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THE FRANKLIN
GLOBE
MANUAL.

THOY, N. Y.:

PUBLISHED BY

MOORE & NIMS.



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A. B. Knight

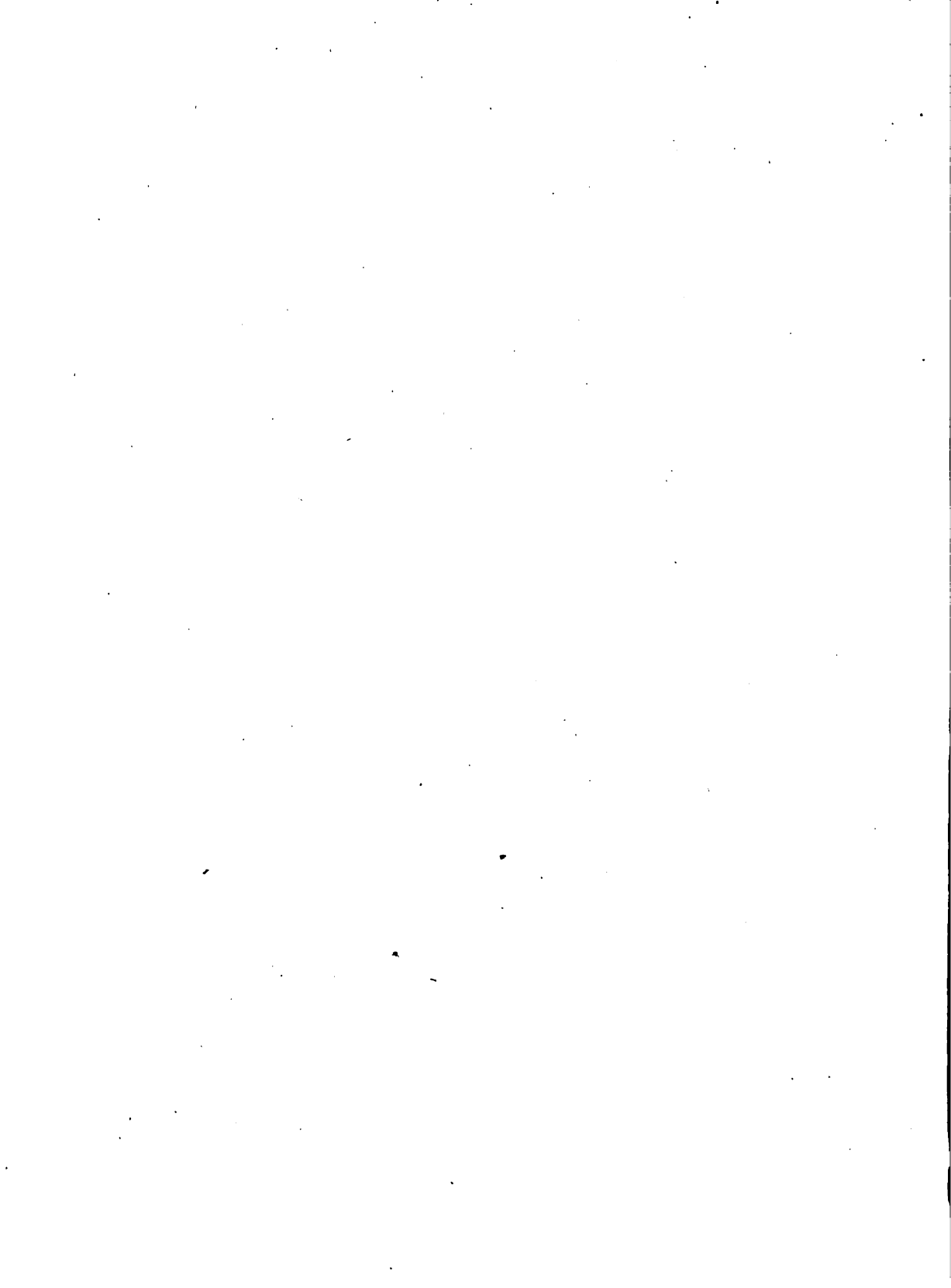
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It is intended to be used in classes as a text book, with the Globes before the class, and while it will bring Globes into more practical use, Teachers will, we think, find it an efficient aid in imparting elementary Geography and Astronomy.

Copies for examination, with a view to introduction, will be sent by mail, post paid, on the receipt of 27 cents in stamps.

Address, MOORE & NIMS, Troy, N. Y.

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MOORE AND NIMS.

1858.

THE
FRANKLIN GLOBE
MANUAL:

AN AID TO THE STUDY OF
GEOGRAPHY AND ASTRONOMY
WITH THE USE OF
ARTIFICIAL GLOBES.

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P R E F A C E.

THE publishers having been frequently requested to furnish a work which should aid both the teacher and the student in the use of Artificial Globes, have prepared the following pages.

As most of the works on the Use of the Globes are too voluminous and scientific to meet the need of many schools, the present has been made as small as is consistent with a clear presentation of the subject. While much that is foreign to the design—though given by other authors—has been excluded, it is believed that all necessary information has been retained.

Without severe and patient study—not of books alone, but also of the heavens themselves—none can become Astronomers. Yet no one should be *wholly* ignorant of that system to which our earth belongs, and of the simple laws which govern it.

Still more important is it that correct ideas, in regard to the shape, size, and *relative* position of the various natural and political divisions of the earth's surface, should be entertained. The study of Geography, with no other aid than that afforded by the Map, usually results in confused impressions of relative positions; for as the representations of the Earth's surface are all made upon planes, the continents, islands, &c., seem distorted, and their relative positions and distances changed. For example: A student may remember the Map of the Eastern and Western Hemispheres, and may have a tolerably correct idea of the situation of England with respect to France; but he must pause awhile, and, in imagination, join the two Hemispheres before he can determine its position in reference to New York. And still more difficult will it be for him to gain a correct idea of the voyage from China, across the Pacific, to our Western shores; for after following the Eastern course to the right-hand edge of the Eastern Hemisphere, he must apparently go backward to the left-hand edge of the Map of the Western Hemisphere, and then begin his easterly voyage again.

The Globe represents the countries, oceans, &c., as actually situated upon the earth, thus destroying many of the sources of error which are found in the use of Maps alone, and becoming the most useful and powerful ally of the teacher of Geography.

To render the use of the Globes simple and practical, has been the object of the publishers; and they trust that their efforts may not be wholly in vain.

The principal part of the work has been taken from an English treatise by THOMAS TATE; such corrections and additions having been made as were rendered necessary by the progress of the science of Astronomy.

March 5th, 1858.

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ON THE USE OF THE GLOBES.

THE TERRESTRIAL GLOBE.

DEFINITIONS AND EXPLANATIONS.

1. A **GLOBE** or sphere is a round body, whose surface is everywhere at the same distance from a point within it called the center.

A **HEMISPHERE** is half the surface of the globe. The horizon divides the upper from the lower hemisphere in the heavens; the equator separates the northern from the southern on the earth; and the metallic meridian standing on any place on the terrestrial globe divides the eastern from the western hemisphere.

The pole of a great circle on a sphere is everywhere 90 degrees distant from it.

2. All circles on the globe are supposed to be divided into 360 equal parts, called degrees. Each quadrant of the circle, therefore, contains 90 degrees. By means of these degrees the magnitudes of angles are measured.

3. The **TERRESTRIAL GLOBE** is an artificial representation of the earth. On this globe the four great divisions of the world, the different empires, kingdoms, and countries, the chief cities, seas, rivers, etc., are truly represented, according to their relative situation on the surface of the earth. The diurnal motion of this globe is from west to east.

4. The **AXIS OF THE EARTH** is an imaginary line, passing through the center, upon which the earth turns.

This line is represented, in the artificial globe, by the wire which passes through the north and south poles.

5. The **POLES OF THE EARTH** are the two extremities of the axis. One pole is called the **NORTH OR ARCTIC POLE**, the other, the **SOUTH OR ANTARCTIC POLE**.

6. The **EQUATOR** is a great circle passing round the globe at equal distances from the poles. It divides the globe into the **NORTHERN** and **SOUTHERN HEMISPHERES**.

The **EQUINOCTIAL** is the equator referred or extended to the heavens. When the sun appears on the equinoctial, the days and nights are equal all over the world.

7. **MERIDIANS** OR **LINES OF LONGITUDE** are semicircles extending from pole to pole: These lines cut the equator at right angles.

The meridian passing through Greenwich is called the **FIRST MERIDIAN**.

8. The **BRAZEN MERIDIAN** is the circle of brass within which the artificial globe turns on two axes representing the poles of the earth. One half of the brass meridian is

graduated from the equator to the poles, that is, the point over the equator is marked 0, and the point over the poles is marked 90—this enables us to find the latitude of a place; the other half of the brass meridian commences with 0 at the pole and ends with 90 at the equator—this enables us to elevate the pole to the latitude of the place.

Great circles divide the globe into two equal parts, as the equator, ecliptic, and the colures.

Small circles divide the globe into two unequal parts, as the tropics, polar circles, parallels of latitude, etc.

9. The **LONGITUDE OF A PLACE** is the distance of the meridian passing through that place, from the first meridian, reckoned in degrees on the equator. Longitude is either east or west, according as the place lies to the east or west of the first meridian. The edge of the brazen meridian is usually employed for drawing a meridian through any given place.

10. **PARALLELS OF LATITUDE** are small circles drawn parallel to the equator.

The **POLAR DISTANCE OF A PLACE** is its distance from either of the poles.

11. The **LATITUDE OF A PLACE** is its distance north or south from the equator, reckoned in degrees on the brass meridian.

Parallels of celestial latitude are small circles drawn on the celestial globe parallel to the ecliptic.

Parallels of declination are small circles parallel to the equinoctial on the celestial globe, and are similar to the parallels of latitude on the terrestrial globe.

12. The **TROPICS** are two small circles drawn parallel to the equator at the distance of $23\frac{1}{2}$ degrees from it. The tropic in the northern hemisphere is called the **TROPIC OF CANCER**, and that in the southern hemisphere the **TROPIC OF CAPRICORN**.

13. The **POLAR CIRCLES** are two small circles drawn parallel to the equator at the distance of $23\frac{1}{2}$ degrees from the poles. The north polar circle is called the **ARCTIC CIRCLE**, and the south polar one the **ANTARCTIC CIRCLE**.

14. The **ZONES**. The surface of the earth is divided by the tropics and polar circles into five parts, called the zones. The portion lying between the tropics of Cancer and Capricorn, is called the **TORRID ZONE**; between the tropic of Cancer and the Arctic circle, the **NORTH TEMPERATE ZONE**; between the tropic of Capricorn and the Antarctic circle, the **SOUTH TEMPERATE ZONE**; between the Arctic circle and the north pole, the **NORTH FRIGID ZONE**; between the Antarctic circle and the south pole, the **SOUTH FRIGID ZONE**.

15. The **ECLIPTIC** is a great circle representing the sun's apparent path throughout the year. It touches the tropics of Cancer and Capricorn, and is inclined to the equator at an angle of $23\frac{1}{2}$ degrees. The two points where it cuts the equator, or equinoctial, are called the **EQUINOCTIAL POINTS**.

16. **SIGNS OF THE ZODIAC**. The ecliptic is divided into 12 equal parts, called the signs of the zodiac; each part, therefore, contains 30 degrees. There are six northern

signs, and six southern ones. The sun appears in the former during our spring and summer months, and in the latter, during our autumn and winter months: the days on which the sun enters the different signs are as follows:

NORTHERN SIGNS OF THE ZODIAC.

SPRING SIGNS.

- ♈ *Aries*, the Ram, 21st of March.
 ♉ *Taurus*, the Bull, 20th of April.
 ♊ *Gemini*, the Twins, 21st of May.

SUMMER SIGNS.

- ♋ *Cancer*, the Crab, 21st of June.
 ♌ *Leo*, the Lion, 23d of July.
 ♍ *Virgo*, the Virgin, 23d of August.

SOUTHERN SIGNS OF THE ZODIAC.

AUTUMNAL SIGNS.

- ♎ *Libra*, the Balance, 22d of September.
 ♏ *Scorpio*, the Scorpion, 23d of October.
 ♐ *Sagittarius*, the Archer, 22d of Novem.

WINTER SIGNS.

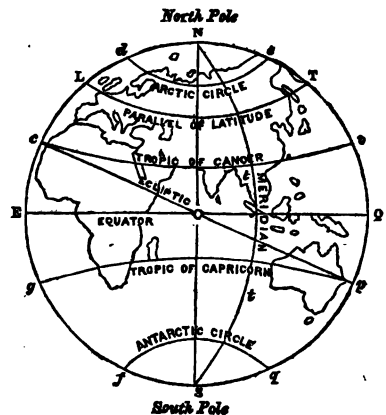
- ♑ *Capricornus*, the Goat, 21st of Decem.
 ♒ *Aquarius*, the Waterman, 20th of Jan.
 ♓ *Pisces*, the Fishes, 19th of February.

17. The EQUINOCTIAL POINTS (that is, the two points where the equator cuts the ecliptic) are Aries and Libra. The former point is called the VERNAL EQUINOX, and the latter the AUTUMNAL EQUINOX. When the sun is in either of these points, the days and nights are equal all over the world.

18. The SOLSTITIAL POINTS are the points where the ecliptic touches the tropics of Cancer and Capricorn. When the sun is in or near these points, the variation in the length of the days is scarcely perceptible. When the sun enters Cancer, it is the longest day to all the inhabitants in the northern hemisphere, and the shortest day to those in the southern hemisphere. On the contrary, when the sun enters Capricorn, it is the shortest day to the people who live in the northern hemisphere, and the longest to those who live in the southern hemisphere.

19. The COLUMES are two great circles which pass through the poles: one of them, called the EQUINOCTIAL COLUME, passes through the equinoctial points; the other, called the SOLSTITIAL COLUME, passes through the solstitial points.

The principal lines on the globe, which have just been described, are represented in the annexed figure: thus *ns* represents the axis of the earth; *N*, the north pole; *s*, the south pole; *eq*, the equator; *eqn*, the northern hemisphere; *eqs*, the southern hemisphere; *nts*, a meridian; *lt*, a parallel of latitude; *ln*, the polar distance of *l*; *cv*, the tropic of Cancer; *gp*, the tropic of Capricorn; *de*, the arctic circle; *fq*, the



antarctic circle ; the surface of the earth lying between *cv* and *gp*, the torrid zone ; between *cv* and *de* the north temperate zone ; between *de* and the north pole, the north frigid zone ; between *gp* and *fq*, the south temperate zone ; and between *fq* and the south pole, the south frigid zone ; *cp*, the ecliptic ; *c*, one of the equinoctial points ; *c* and *p*, the solstitial points ; the great circle *ncs* going round the earth, the equinoctial colure ; and *ncsv*, the solstitial colure.

20. The ZENITH is that point in the heavens directly over our heads.

21. The NADIR is that point in the heavens which lies directly below our feet.

22. ANTIPODES are those people who live on opposite sides of the earth, and therefore walk feet to feet. Their latitudes, longitudes, days and nights, seasons of the year, are all contrary to each other.

23. The HORIZON is of two kinds ; the sensible or visible horizon, and the rational or true horizon.

The SENSIBLE or visible horizon, is that circle on the earth which bounds our view.

The RATIONAL or true horizon, is a great circle of the heavens, everywhere 90 degrees from the zenith.

24. The ALTITUDE of any object in the heavens is its distance from the horizon. When the body is on a meridian, such as the sun at noon, the altitude is then called the MERIDIAN ALTITUDE.

25. The ZENITH DISTANCE of a celestial body is its distance from the zenith.

26. The QUADRANT OF ALTITUDE is a thin, flexible slip of brass, divided upward from 0 to 90 degrees, and downward from 0 to 18 degrees. It admits of being screwed to the brazen meridian. The upper divisions are used for finding the distances between places on the earth, the altitude of the heavenly bodies, etc., and the lower divisions are used for finding the duration of twilight.

ALMACANTERS OR PARALLELS OF ALTITUDE, are imaginary circles, parallel to the horizon, and serve to show the height of the sun, moon, and stars. These circles are not drawn on the globe, but they may be described for any latitude by the quadrant of altitude.

27. AZIMUTH or VERTICAL CIRCLES, are great circles passing through the zenith and nadir points, cutting the horizon at right angles. The altitudes of the heavenly bodies are measured on these circles. This is done by screwing the quadrant of altitude on the zenith of the place of observation, and moving the slip of brass until its graduated edge passes through the body.

28. The AZIMUTH of any celestial body is an arc of the horizon lying between a vertical circle passing through the body, and the north or south points of the horizon.

29. The AMPLITUDE of any celestial body is the distance at which it rises from the east or sets from the west.

30. The CARDINAL POINTS are the east, west, north, and south points of the horizon.

The cardinal points in the heavens are the zenith, the nadir, and the points where the sun rises and sets.

31. MARINER'S COMPASS consists of a card, representing the horizon, divided into thirty-two equal parts, called points of the compass, together with a magnetic needle, which always turns its north pole *toward* the north. By this valuable instrument seamen direct the course of their ships, and engineers and travelers can at any time ascertain the cardinal points of the horizon.

The needle does not always exactly point north and south. In laying down a meridian line, an allowance must be made for this variation.

The compass is sometimes placed beneath the artificial globe for setting it due north and south.

32. The WOODEN HORIZON, surrounding the artificial globe, represents the rational horizon. It is usually divided into seven concentric circles: The *first* is for finding the *amplitude* of heavenly bodies. The *second* for finding their *azimuth*. The *third* contains the thirty-two points of the *compass*. The *fourth* contains the twelve signs of the *zodiac*, with the degrees of each sign. The *fifth* contains the days of the month, corresponding to every degree of the sun's place in the ecliptic, as indicated in the fourth circle. The *sixth* contains the equation of time, that is, the difference of time between a clock and a sun dial. The *seventh* contains the twelve calendar months.

33. The HOUR CIRCLE is a flat ring of brass, turning under the brazen meridian on the axis or pole of the artificial globe. It is divided into twenty-four equal parts, representing hours. It is used for finding the difference of time between any given places, the length of the day, etc.

On the common school globes the hour circle is drawn around the north pole, and is furnished with a brass index, which is attached to the axis.

34. The DECLINATION of the sun is his distance, north or south, from the equinoctial. At the equinoxes, he has no declination; at the tropic of Cancer, he has attained his greatest northern declination; and at the tropic of Capricorn, he has attained his greatest southern declination.

35. The RIGHT ASCENSION of the sun is the distance of the meridian, passing through the sun's place in the ecliptic, from the equinoctial point Aries, reckoned in degrees eastward on the equator or equinoctial.

36. A RIGHT SPHERE is that position of the earth where the poles are in the horizon, and the equator passes through the zenith and nadir. The people who live at the equator have this position of the sphere.

37. A PARALLEL SPHERE is that position of the earth where the poles are in the zenith and nadir, and the equator coincides with the horizon. If there were any people living at the poles they would have this position of the sphere.

38. An OBLIQUE SPHERE is that position of the earth where the equator cuts the

horizon obliquely. All the people on the earth (excepting those that live at the equator and the poles) have this position of the sphere.

The **ANALEMMA**, on the terrestrial globe, is a diagram placed in some vacant space on its surface, extending through the torrid zone, in which is entered the sun's declination, or distance from the equinoctial, corresponding to the different months and days throughout the year. The month and day of the month being given, the declination at the time may be found; or the declination north or south being given, the time when the sun has that declination can be ascertained, as well as the sign and degree of the ecliptic.

PROBLEMS ON THE TERRESTRIAL GLOBE.

PROBLEM I.—*To find the latitude and longitude of any given place.*

RULE.—Bring the given place to the east edge of the metallic meridian: the degree directly over the place is the latitude; and the degree on the equator cut by the metallic meridian is the longitude.

The latitude of a place may be north or south, and the longitude east or west.

EXAMPLES.

1. What is the latitude and longitude of Paris?

Answer. 48° 50' north latitude, and 2° 20' east longitude.

Required the latitudes and the longitudes of the following places:—

2. Rome; 3. South Cape, Spitzbergen; 4. Malta; 5. Cape Horn; 6. Azores.
7. What is the latitude and longitude of the North Pole?
8. What is the greatest latitude a place can have?
9. What is the greatest longitude a place can have?
10. What part of the earth is that which has no latitude?

ANSWERS.

(2.) 41° 54' N. latitude, and 12° 27' E. longitude.

(3.) 76° 32' N. latitude, and 13° 45' E. longitude.

(4.) 35° 53' N. latitude, and 14° 30' E. longitude.

(5.) 55° 58' S. latitude, and 67° 11' W. longitude.

(6.) 39° N. latitude, and 28° W. longitude.

(7.) 90° N. latitude. (8.) 90 degrees. (9.) 180° east or west longitude. (10.)

The equator.

PROBLEM II.—*To find any place on the globe having its latitude and longitude given.*

RULE.—Find the given longitude on the equator, and bring it to the metallic meridian; find the given latitude on the metallic meridian, and the place immediately under will be the place required.

EXAMPLES.

(1.) What place has 20° north latitude, and 76° west longitude?

Answer. The Island of Cuba.

What places have nearly the following latitudes and longitudes?

(2.) 54° N. latitude, and $18\frac{1}{2}^{\circ}$ E. longitude.

(3.) 30° N. latitude, and 31° E. longitude.

(4.) 21° S. latitude, and $55\frac{1}{2}^{\circ}$ E. longitude.

(5.) 29° N. latitude, and 18° W. longitude.

(6.) 34° S. latitude, and 18° E. longitude.

Answers. (2.) Dantzic; (3.) Cairo; (4.) Island of Bourbon; (5.) Canary Islands, Palma; (6.) Cape of Good Hope town.

PROBLEM III.—*To find all those places which have the same latitude as a given place.*

RULE.—Bring the given place to the metallic meridian and find its latitude; turn the globe slowly round, and all places which pass under the observed latitude will be those required.

All places in the same latitude have the same seasons and the same length of day and night; but, owing to various physical causes (such as the relative distribution of land and water) they may not have the same temperature.

EXAMPLES.

1. What places have nearly the same latitude as Constantinople?

Answer. Naples; Pekin; Philadelphia, &c.

What places have nearly the same latitude as the following:—

2. London; 3. Alexandria; 4. Rome?

5. What places have nearly the same length of days as Malta?

Answers. (2.) Rotterdam, &c; (3.) Cummin's Island, China, &c.; (4.) Nova Scotia; (5.) Cape St. Vincent, Portugal, &c.

PROBLEM IV.—*To find all those places which have the same longitude as a given place.*

RULE.—Bring the given place to the metallic meridian; all places under the edge of the metallic meridian, from pole to pole, have the same longitude.

The people living in all those places which have the same longitude, have noon and all other hours of the day alike.

EXAMPLES.

1. What places have nearly the same longitude as Madeira?

Answer. Hecla; Teneriffe; Cape Blanco, &c.

2. What inhabitants of the earth have nearly the same time as the people of the Cape of Good Hope?

3. What places have nearly the same longitude as Gibraltar?

Answers. (2.) Dantzic, Stockholm, &c.; (3.) St. David's Head, Wales, &c.

PROBLEM V.—*To find the distance between two places.*

RULE.—Lay the edge of the quadrant of altitude over the two places, so that the point marked 0 may be over one of them; then the number of degrees over the other place will give the number of degrees that they are apart.

Multiply the number of degrees by 60, and the product will give the geographical miles; or multiply the number of degrees by $69\frac{1}{8}$, and the product will give the distance in English miles.

Or, take the distance between the two places with a thread, apply that distance to the equator, and it will show how many degrees are contained in the distance.

EXAMPLES.

1. What is the distance between London and Madeira?

Answer. About $22\frac{1}{2}^{\circ}$, or 1350 geographical miles, or about 1554 English miles.

What is the distance between the following places:—2. London and Constantinople; 3. Cape Verd Isles and the Cape of Good Hope; 4. London and Petersburg?

5. What is the distance of Land's End from Jamaica?

6. Suppose a ship to sail from Liverpool to Madras in the following track: from Liverpool to Cape Verd Islands, thence to St. Helena, thence to the Cape, thence to Mauritius, thence to Ceylon, and thence to Madras; how many English miles are there in the voyage?

ANSWERS.

(2.) 1320 geographical miles, and 1535 English miles.

(3.) 3900 geographical miles, and 4491 English miles.

(4.) 1140 geographical miles, and 1312 English miles.

(5.) 3840 geographical miles, and 4421 English miles.

(6.) About 185° , or 11,100 geographical miles, or about 12,783 English miles.

PROBLEM VI.—*The hour of the day being given at one place, to find what hour it is at any other place.*

RULE.—Bring the place at which the time is given to the metallic meridian; turn the hour circle until the given hour is brought to the brass meridian, or set the hour index to the given hour; turn the globe until the other place is brought under the metallic meridian, and the hour on the hour circle, which is under the brass meridian, or under the index, will be the time required.

Or thus, by calculation.—Find the difference of longitude between the two places, allow an hour for every 15 degrees, and 4 minutes of time for every degree, and the time thus obtained will give the difference of time between the two places. If the place at which the time is required lies to the east of the other place, this difference of time must be added to find the time at the place required; but if to the west, it must be subtracted. (See ASTRONOMY, Art. 22, and EXERCISES, p. 75.)

EXAMPLES.

1. When it is 4 o'clock in the afternoon at London, what time is it at Petersburg?

Answer. Six o'clock in the evening.

Or thus, more accurately by calculation.—The difference of longitude between London and Petersburg is $30^{\circ} 25'$. Here the 30 degrees exactly give 2 hours difference of time, and to convert the remaining $25'$ into time, we have

$$= \frac{35}{60} \text{ degrees;}$$

\therefore No. minutes corresponding to $25'$

$$= \frac{25}{60} \times 4 = \frac{5}{3} = 1\frac{2}{3},$$

which, added to the 2 hours, gives 2 hours $1\frac{2}{3}$ minutes for the difference of time.

Now, as Petersburg lies to the east of London, the time at the former place will be 2 hours $1\frac{2}{3}$ minutes later than it is at London; that is, the time at Petersburg will be $1\frac{2}{3}$ minutes past 6 in the evening.

2. When it is 1 o'clock in the afternoon at Alexandria, what time is it at Philadelphia?

Answer. Seven o'clock in the morning.

Or thus, more accurately by calculation.—

Longitude of Alexandria = $30^{\circ} 16'$ east.

Longitude of Philadelphia = $75^{\circ} 19'$ west.

\therefore Difference of longitude = $105^{\circ} 35'$

\therefore Difference of time in hours = $\frac{105}{15} = 7$ hours.

“ in minutes = $\frac{35}{60} \times 4 = \frac{7}{3} = 2\frac{1}{3}$ minutes.

\therefore Total difference of time = 7 hours $2\frac{1}{3}$ minutes.

Now as Philadelphia lies to the west of Alexandria, the time of the former place will be 7 hours $2\frac{1}{3}$ minutes earlier than it is at the latter place; hence the time at Philadelphia will be $57\frac{2}{3}$ minutes past 5 in the morning.

3. When it is 4 o'clock in the afternoon at Cape Horn, what time is it at the Island of St. Helena?

4. When it is 10 o'clock in the morning at Nankin in China, what time is it at Plymouth?

ANSWERS.

(3.) 6 minutes past 8 o'clock in the evening nearly.

(4.) $\frac{3}{4}$ past 1 o'clock in the morning nearly.

PROBLEM VII.—*Given the difference of time at any two places to find their difference of longitude.*

RULE.—Bring the first meridian to the metallic meridian; set the hour index at 12 o'clock; turn the globe until the given time is brought under the metallic meridian; and the degree of the equator cut by the metallic meridian will be the difference of longitude.

Or thus by calculation.—Allow 15 degrees difference of longitude for every hour in the difference of time, or 1 degree for every 4 minutes of time.

EXAMPLES.

1. When it is noon at a certain place it is 8 o'clock in the morning at London; required the longitude of the place.

Answer. 60° east longitude.

Or thus, by calculation.—Here the difference of time is 4 hours.

∴ Difference longitude = $4 \times 15 = 60$ degrees. As the time at London is before that of the place, it follows that it must have 60 degrees east longitude.

2. When it is 10 o'clock in the morning at London, at what places will it be noon?

3. What places will have noon 7 hours 55 min. before London?

ANSWERS.

(2.) To all places having 30° E. long.;—Petersburg, &c.

(3.) To all places having 118 $\frac{3}{4}$ ° E. long.;—Nankin, &c.

PROBLEM VIII.—*To find the length of a degree in any given parallel of latitude.*

RULE.—Lay the edge of the quadrant of altitude parallel to the equator between any two meridians (15 degrees of longitude apart), then the number of degrees intercepted between them, multiplied by 4, will give the number of geographical miles contained in a degree of the given parallel very nearly. To find the number of English miles, multiply the geographical miles by 69 $\frac{1}{4}$ and divide by 60.

EXAMPLES.

1. How many geographical and English miles are there contained in a degree in the latitude of 40°?

Here the distance between two meridians (15 degrees apart) in the parallel of 40°, is 11 $\frac{1}{2}$ degrees of the equator nearly; hence we have

Length of 15 degrees longitude on parallel 40°

= 11 $\frac{1}{2}$ degrees of the equator,

= 11 $\frac{1}{2}$ × 60 geographical miles;

∴ Length of one degree longitude on parallel 40°

= $\frac{11\frac{1}{2} \times 60}{15} = 11\frac{1}{2} \times 4 = 46$ geographical miles,

= $\frac{46 \times 69.1}{60}$ English miles = 52.97 English miles.

How many geographical and English miles are there contained in a degree in the following latitudes :—

(2.) 30° ; (3.) 51° ; (4.) 56° ; (5.) 60° ?

ANSWERS.

(2.) 51.9 geographical miles, or 59.7 English miles.

(3.) 37.7 geographical miles, or 43.4 English miles.

(4.) 33.5 geographical miles, or 38.5 English miles.

(5.) 30 geographical miles, or $34\frac{1}{2}$ English miles.

PROBLEM IX.—*To find the antipodes of a given place.*

RULE.—Place the two poles of the globe in the horizon; turn the globe until the given place comes to the eastern part of the horizon; observe the number of degrees that the place is to the north (or south) of the east point of the horizon, and the same number of degrees counted south (or north), from the west point of the horizon, will give the antipodes required.

EXAMPLES.

1. Required the antipodes of London.

Answer. Antipodes Island, near the Island of New Zealand.

Required the antipodes of the following places :—2. The Island of Bermudas; 3. Cape Horn; 4. Cape of Good Hope; 5. The Azores.

Answers. (2.) The southwest part of New Holland; (3.) The east of Lake Baikal; (4.) The north of the Sandwich Islands; (5.) East of Cape Howe.

PROBLEM X.—*To rectify the globe for a given place.*

RULE.—Elevate or raise the corresponding pole as many degrees above the wooden horizon as are equal to the latitude of the place. (See ASTRONOMY, Art. 27.)

If the globe be now turned round, so as to bring the place to the metallic meridian, it will be seen that the place occupies the zenith of the globe; that is to say, the wooden horizon forms the true horizon to the place.

PROBLEM XI.—*To find the sun's place in the ecliptic for any given day.*

RULE.—Find the month, and the mark corresponding to the day of that month, in the outer circle of the wooden horizon; then the coincident mark in the circle containing the signs of the zodiac will give the sun's place in the ecliptic, which may then be found upon the globe.

PROBLEM XII.—*To find the sun's declination for a given day of a given month, and to find the places to which the sun will be vertical on that day.*

RULE.—Find the sun's place in the ecliptic for the given day (Prob. XI.); bring that point of the ecliptic to the metallic meridian, and the degree directly over it on the metallic meridian is the declination north or south. Turn the globe round, and every

place which passes under that degree of the metallic meridian will have the sun vertical on that day.

The declination of the sun obviously gives the latitude of the places which will have the sun vertical.

The sun can only be vertical to places lying within the torrid zone.

EXAMPLES.

1. Required the declination of the sun on the 11th of July. What will be the latitude of the places to which the sun will be vertical on that day?

Answer. 22° north declination; and 22° north latitude, Lessoe Island, Cattegat, &c.

To find the declination and the places to which he will be vertical on the following days:—

2. 3d of October; 3. 24th of July; 4. 10th of January; 5. 10th of June.

Answers. (2.) 4° south declination, and 4° south latitude.

(3.) 20° north declination, and 20° north latitude.

(4.) 22° south declination, and 22° south latitude.

(5.) 23° north declination, and 23° north latitude.

PROBLEM XIII.—*To find the hour at which the sun rises and sets at a given place, for any given day.*

RULE.—Rectify the globe for the latitude of the place (see Prob. X.); find the sun's place in the ecliptic (see Prob. XI.), and bring it to the metallic meridian. Set the index of the hour circle to XII.; turn the globe till the sun's place comes to the eastern edge of the wooden horizon, and the index will show the hour at which the sun rises; then turn the globe till the sun's place comes to the western edge of the wooden horizon, and the index will show the hour at which the sun sets.

The length of the day is found by doubling the hour of sunset.

The amplitude of the sun will be found by simply observing the point on the wooden horizon, which is cut by the sun's place in the ecliptic at the time of rising or setting.

EXAMPLES.

1. At what time will the sun rise and set to the people of London on the 21st day of December? Required also the sun's amplitude on this day.

Answer. Rises $\frac{1}{4}$ before 8, and sets $\frac{1}{4}$ past 4; the amplitude about 36° to the south of the east point of the horizon.

2. At what time will the sun rise and set to the people of Rome on the 1st day of April, &c.?

3. What is the length of the longest day to the inhabitants of Paris? At what distance from the east point of the horizon does the sun rise on this day?

4. Show that the day is always 12 hours long to the people living at the equator.

Show that the 21st of June is the longest day to the inhabitants of the northern hemisphere, and that the 21st of December is their shortest day.

Required the length of the shortest day to the inhabitants of the following places : 5. Edinburgh ; 6. New York.

Answers. (2.) Rises $\frac{1}{4}$ before 6, and sets $\frac{1}{4}$ after 6 ; amplitude 5° north of the east point ; (3.) Length of the day 16 hours, and about 37° north of the east point ; (5.) $6\frac{1}{2}$ hours ; (6.) 9 hours.

PROBLEM XIV.—*To find the sun's meridian altitude at a given place on a given day.*

RULE.—Rectify the globe for the latitude of the place ; bring the sun's place in the ecliptic for the given day to the metallic meridian ; count the number of degrees on the metallic meridian, between the sun's place and the horizon for the meridian altitude required.

Or thus.—Find the declination of the sun, and add it to the co-latitude of the place when the declination and latitude are of the same name, but subtract it when they are of different names.

EXAMPLES.

1. What is the sun's meridian altitude at London on our midsummer day ?

Answer. 62° . This is the greatest elevation of the sun above the horizon of London.

Or thus, by calculation.—Here the declination and latitude are of the same name. On this day the declination of the sun is $23\frac{1}{2}^{\circ}$ north, and the co-latitude is 90° less by $51\frac{1}{2}^{\circ}$ or $38\frac{1}{2}^{\circ}$; hence the meridian altitude $= 38\frac{1}{2} + 23\frac{1}{2} = 62^{\circ}$.

2. What is the sun's meridian altitude at London on our mid-winter day ?

Answer. 15° . This is the least meridian altitude of the sun to the inhabitants of London.

Or thus, by calculation.—Here the declination and latitude have different names. In this case, therefore, we have the meridian altitude $= 38\frac{1}{2} - 23\frac{1}{2} = 15^{\circ}$.

3. Required the sun's meridian altitude at Paris on the 1st of August.

4. What is the sun's meridian altitude at London on the 2d of February ?

What would be the meridian altitude of the sun on the 21st of June to the following places :—

5. The north pole ; 6. The arctic circle ; 7. The equator ?

Answers. (3.) $59^{\circ} 10'$; (4.) $21\frac{1}{2}^{\circ}$; (5.) $23\frac{1}{2}^{\circ}$; (6.) 47° ; (7.) $66\frac{1}{2}^{\circ}$, or $23\frac{1}{2}^{\circ}$ from the zenith.

PROBLEM XV.—*To find the altitude of the sun at any given place and hour ; and also his azimuth.*

RULE.—Rectify the globe for the latitude of the given place ; bring the sun's place to the metallic meridian ; set the index to XII. ; turn the globe till the index points at the given hour ; fix the quadrant of altitude on the metallic meridian, at the degree

of latitude of the given place, and lay its edge over the sun's place; then count the number of degrees on the quadrant between this point and the wooden horizon, and it will give the altitude required.

The distance of the point, where the edge of the quadrant of altitude cuts the wooden horizon, from the north or south points, will give the sun's azimuth.

EXAMPLES.

1. Required the sun's altitude, &c. at 7 o'clock in the morning on the 5th of May, to the inhabitants of London.

Answer. Altitude $21\frac{1}{2}^{\circ}$, and azimuth 90° from the north point of the horizon.

2. Required the sun's altitude and azimuth at 4 o'clock in the afternoon on the 2d of July, to the inhabitants of Petersburg.

3. Required the same as in the last example to the inhabitants of London.

Answers. (2.) 35° altitude, and azimuth 75° from the south point; (3.) 37° altitude, and azimuth 80° from the south point.

PROBLEM XVI.—*The hour and day being given at a particular place, to find the place where the sun is then vertical.*

RULE.—Find the sun's declination for the given day (see Prob. XII.); this gives the latitude of the required place; bring the given place to the metallic meridian; set the index to the given hour; turn the globe till the index points to XII. noon; then all the places under the metallic meridian will have noon at the given time, and the place whose latitude is the same as the sun's declination will have the sun vertical.

EXAMPLES.

1. To what place will the sun be nearly vertical on the 5th day of February, when it is 23 minutes past noon at London?

Answer. The island of St. Helena.

2. To what place will the sun be nearly vertical on the 30th day of April, when it is 34 minutes past 1 o'clock in the afternoon at London?

Answer. To the island of St. Jago, one of the Cape Verd isles.

3. When it is 40 minutes past 6 o'clock in the morning at London on the 25th of April, where is the sun vertical?

Answer. Madras.

4. When it is 4 o'clock in the afternoon at London on the 18th of August, where is the sun vertical?

Answer. Barbadoes.

PROBLEM XVII.—*A place within the torrid zone being given, to find those two days of the year on which the sun will be vertical to the given place.*

RULE.—Bring the given place to the metallic meridian, and observe its latitude; turn the globe on its axis, and mark what two points of the ecliptic pass under that

latitude; seek those two points of the ecliptic in the circle containing the signs of the zodiac, on the wooden horizon, and opposite to them will be found the days required.

EXAMPLES.

1. On what two days of the year will the sun be vertical to the inhabitants of St. Helena?

Answer. On the 5th day of February, and on the 6th day of November.

2. On what two days of the year will the sun be vertical to the inhabitants of Madras?

Answer. On the 25th day of April, and on the 18th of August.

PROBLEM XVIII.—*The hour and day being given at a particular place, to find the places where the sun is then rising or setting, and where it is noon or midnight.*

• RULE.—Rectify the globe for the latitude of the given place; find (by Prob. XVI.) the place to which the sun is vertical at the given time, and bring that place to the metallic meridian; then all places on the western edge of the wooden horizon will have the sun rising; all those on the eastern edge will have him setting: all those places under the upper half of the metallic meridian will have noon; and all those under the lower half of the metallic meridian will have midnight.

EXAMPLES.

1. When it is 52 minutes past 4 o'clock in the morning at London on the 5th of March, to find the places where the sun is then rising, or setting, and where it is noon or midnight?

Answer. The sun is *rising* at the White Sea, Morea, Petersburg, &c.; *setting* at the eastern coast of Kamtschatka, between the Friendly and Society Islands, &c.; *noon* at Sunda Islands, Cochin China, &c.; *midnight* at New York, St. Domingo, &c.

2. Where is the sun rising, setting, &c., when it is 4 o'clock in the afternoon at London on the 25th day of April?

Answer. *Rising* at Owwhyhee, &c.; *setting* at the Cape of Good Hope, &c.; *noon* at Buenos Ayres, &c.; and so on.

PROBLEM XIX.—*To illustrate the three positions of the sphere, RIGHT, PARALLEL, and OBLIQUE, so as to show the aspect of the sun, &c., at different times of the year.*

1. THE RIGHT SPHERE.—The people at the equator have this sphere; the north polar-star always appears in their horizon. To place the artificial globe in this position, bring the two poles to the wooden horizon; turn the globe round; then the following facts may be readily illustrated:

AT THE EQUATOR the days are always twelve hours long, whatever may be the position of the sun in the ecliptic; for the sun and all the heavenly bodies will APPEAR to revolve round the earth in circles parallel to the equinoctial, and the diurnal arc above the horizon will always be equal to that which is below it. The whole of the heavens

may be seen at the equator, in the course of a day; and in the course of the year all the stars in the heavens may be seen; whereas, at the poles, only one-half of the heavens can be seen. On the equinoxes, the sun passes directly over the heads of the people at the equator: when the sun is in the northern half of the ecliptic, at noon his aspect is north; and, on the contrary, when the sun is in the southern half of the ecliptic, at noon his aspect is south.

2. THE PARALLEL SPHERE.—The people at the north pole, if there were any living there, would have this sphere; the north polar-star in the heavens would appear exactly over their heads. To place the artificial globe in this position, elevate the north pole 90° above the horizon; or, what is the same thing, make the equator to coincide with the wooden horizon.

AT THE POLES, during six months of the year, the sun shines without setting, and during the other six months he never appears above the horizon. On the 21st day of March, when the sun is in the vernal equinox, he will be seen by the people at the north pole (if there were any) to skim along the horizon; and as the sun's northern declination increases, he will appear, day after day, to rise higher above the horizon, until he attains his greatest northern declination ($23\frac{1}{2}^\circ$), and then his elevation above the horizon will be $23\frac{1}{2}^\circ$, that is, it will be equal to his declination; after this, his altitude will gradually decrease until he arrives at the autumnal equinox, when he will again appear to skim along the edge of the horizon; so that he will have been six months above the horizon without setting; after this, he will totally disappear for six months. But there will be twilight until the sun is 18° below the horizon, that is, until he has attained 18° south declination. The same thing will take place with respect to the south pole, but with this difference; while the sun shines upon the north pole, he will be invisible to the supposed people of the south pole, and *vice versa*.

A spectator at the north pole can only see the stars in the northern hemisphere, or those stars which lie on the north of the equinoctial.

3. THE OBLIQUE SPHERE.—All people living on the earth, excepting those at the equator and poles, have this position of the sphere. In this case, the horizon cuts the equator obliquely. To place the artificial globe in this position, elevate the north or south pole, as the case may be, to the latitude of the place where we may conceive a spectator to be placed. Let us suppose, for example, that the north pole is elevated to the latitude of London.

To the people living at London, for six months of the year, the days are more than twelve hours long, and for the remaining six months, they are less than twelve hours long: that is to say, from the 21st of March to the 22d of September, when the sun is on the northern side of the equinoctial, the days are more than twelve hours long; and, on the contrary, from the 22d of September to the 21st of March, when the sun is on the southern side of the equinoctial, the days are less than twelve hours long. At the

vernal equinox (on the 21st of March) the sun shines perpendicularly over the equator, and the days and nights are equal all over the globe; as the sun's northern declination increases, the days also increase in length; for the diurnal arcs described by the sun are unequally divided by the horizon. When the sun has attained his greatest northern declination (June 21st), the days have also attained their greatest length; but they will be at their shortest to the people in the southern hemisphere. After this, the sun's northern declination gradually decreases, and the days also gradually decrease in length; when he arrives at the autumnal equinox (Sept. 22d), the days and nights are again equal: after this, the days become shorter and shorter, as the sun's southern declination increases, until he has attained his greatest southern declination (December 21st), and then the days will be at their shortest with us, but at their greatest length to the people of the southern hemisphere: after this, our days increase in length, and when the sun again arrives at the vernal equinox, the days and nights are again equal.

The duration of twilight is greater with us than it is at the equator, because the diurnal arc of the sun cuts the horizon obliquely, which causes him to take a longer time to get 18° below the horizon; whereas, at the equator, the sun sinks perpendicularly below the horizon, which tends to shorten the duration of twilight.

The people that live in the northern hemisphere can never see those stars which lie towards the south polar-star, and the people in the southern hemisphere can never see those stars which lie towards the north polar-star; but, as already observed, a person at the equator may see all the stars in the heavens, in the course of the year.

PROBLEM XX.—*Any place in the north frigid zone being given, to find how long the sun shines there without setting, and how long he is invisible.*

RULE.—Rectify the globe for the latitude of the place; bring the ascending signs of the ecliptic (the signs going before Cancer) to the north point of the horizon, and observe what degree of the ecliptic is cut by that point; find on the wooden horizon the day and month corresponding to that degree; then from that day the sun begins to shine without setting. Now, bring the descending signs (the signs coming after Cancer) to the north point of the horizon, and observe what degree of the ecliptic is cut by that point; find on the wooden horizon, as before, the day and month corresponding to that degree; then, on that day, the sun ceases to shine without setting. By proceeding in the same manner with the southern point of the horizon, we may find the beginning and end of the period during which the sun is invisible.

Example.—How long will the sun shine without setting, to the inhabitants of the North Cape, in latitude $71\frac{1}{2}^{\circ}$ north?

Answer. The sun begins to shine continually on the 14th of May, and ceases to shine continually on the 30th of July. The longest day is, therefore, 77 days long; that is to say, the sun shines without setting for 77 days. The period during which the sun

will be invisible, extends from the 16th of November to the 27th of January. The longest night is, therefore, 73 days long; that is to say, the sun is never seen by the inhabitants of this place for the period of 73 days.

PROBLEM XXI.—*To find the beginning and end of twilight at a given place on any given day.*

RULE.—Rectify the globe for the latitude of the place; bring the sun's place in the ecliptic on the given day to the metallic meridian; set the hour circle to XII.; screw the quadrant of altitude upon the metallic meridian over the given latitude; turn the globe westward till the sun's place comes to the western edge of the wooden horizon; then the hour circle will show the time of the sun's setting, or the beginning of evening twilight: continue the motion of the globe till the sun's place coincides with 18° on the quadrant of altitude, below the horizon; then the hour circle will show the time at which the evening twilight ends. The duration of twilight is equal to the difference between the time at which it ends, and the time at which it begins. The time at which evening twilight ends, subtracted from 12, will give the beginning of morning twilight, which is of the same duration as the evening twilight.

EXAMPLES.

1. Required the duration of twilight at London on the 22d of September.

Answer. The sun sets at 6 o'clock, and twilight ends at 8 o'clock; consequently, the duration of twilight is 2 hours.

2. Required the duration of twilight at those places which have the same latitude as Edinburgh on the 24th of April.

Answer. 3 hours.

3. What is the duration of twilight at London on the 20th of April?

Answer. 2 hours 18 minutes.

PROBLEM XXII.—*Given the sun's meridian altitude, and the day of the month, to find the latitude of the place.*

RULE.—If the sun was south of the observer when the altitude was taken. Bring the sun's place in the ecliptic to the south side of the metallic meridian; move the metallic meridian till the sun's place is raised above the horizon equal to the given meridian altitude; then the elevation of the north pole will give the latitude of the place. If the sun was north of the observer when the altitude was taken, proceed in the same manner; with this exception, that the sun's place must be brought to the north side of the metallic meridian, and the elevation of the south pole will give the latitude of the place.

EXAMPLES.

1. On the 21st of June, the meridian altitude of the sun was observed to be $69\frac{1}{2}^{\circ}$, and south of the observer; required the latitude of the place.

Answer. 44° north latitude.

2. On the 21st of December, the meridian altitude of the sun was observed to be 25° , and south of the observer; required the latitude of the place.

Answer. $41\frac{1}{2}^{\circ}$ north latitude.

3. On the 10th of May, the meridian altitude of the sun was observed to be 30° . and north of the observer; required the latitude of the place.

Answer. $42^{\circ} 25'$ south latitude.

PROBLEM XXIII.—*To find the angle of position between two given places.*

RULE.—If the two places be on the same meridian, they bear north and south from each other, and therefore their angle of position is 0. When the places are not on the same meridian, proceed as follows: rectify the globe to the latitude of one of the places; bring that place to the metallic meridian, and screw the quadrant of altitude over it; move the quadrant till its edge falls upon the other place; then the point where the edge of the quadrant cuts the wooden horizon will give the angle of position between the two places, which is estimated in degrees from the north point, or it may be reckoned by the points of the compass.

EXAMPLES.

1. Required the angle of position between London and Madras.

Answer. 90° from the north towards the east.

2. Required the angle of position between London and Jamaica.

Answer. The quadrant of altitude falls upon the west point of the horizon; the angle of position is 90° from the north towards the west.

3. What is the angle of position between Madrid and Philadelphia?

Answer. 65° .

PROBLEM XXIV.—*To find all the places to which a lunar eclipse is visible at a given instant.*

RULE.—Find (by Prob. XVI.) the place to which the sun is vertical at the given time; bring the place to the metallic meridian, and rectify the globe to the latitude of that place; then at all places within 70 degrees of this place an eclipse of the sun *may* be visible, especially if it be a total eclipse. For a lunar eclipse, after proceeding as before, set the hour circle to XII. noon; turn the globe till the hour circle is at XII. midnight; then an eclipse of the moon will be visible to all those places which are above the wooden horizon.

EXAMPLES.

1. There was an eclipse of the sun on the 9th of October, 1847, at 29 min. past 7 o'clock in the morning at London; to what places might it be visible?

Answer. To Hindoostan, Arabia, &c.

2. An eclipse of the moon took place on the 26th of January, 1842, at 6 o'clock in the afternoon at London; to what places was it visible?

Answer. Europe, Asia, Australia, and a portion of Africa.

3. An eclipse of the moon took place on the 31st of May, 1844, at 50 min. past 10 in the evening at London; to what places was it visible?

Answer. Europe, Africa, and a portion of Asia.

4. An eclipse of the moon will take place on the 7th of January, 1852, at 30 min. past 6 in the morning at London; to what places will it be visible?

Answer. Visible at London, &c.

PROBLEM XXV.—*To place the terrestrial globe in the sunshine, so that it may represent the actual position of the earth with respect to the sun.*

RULE.—Place the globe directly north and south, by means of the compass, usually placed beneath the globe, taking care to bring the north pole of the needle about 8 degrees to the west of the north point of the compass, which is the allowance at present for the variation; bring the place where you are living to the metallic meridian, and elevate the pole to its latitude; then the globe, with its various lines, &c., will correspond in every respect with the position of the earth, and the imaginary lines, &c., upon it, with respect to the sun. The point to which the sun is vertical, the illuminated hemisphere, &c., may all be at once determined.

PROBLEM XXVI.—*To construct a horizontal dial by the globe for a given latitude.*

RULE.—Place the globe, as in the last problem, directly north and south; rectify the globe to the latitude of the place; bring the first meridian to the metallic meridian; then observe the points where the hour meridians on the globe cut the horizon, and number these points according to the hours of the day: thus the point of the dial at the metallic meridian must be numbered XII., thence XI., X., &c., towards the west for the morning hours, and I., II., &c., for the evening hours. The style of the dial represents the axis of the earth, and must therefore always make with the plane of the horizon, or the plane of the dial-plate, an angle equal to the latitude of the place.

THE CELESTIAL GLOBE.

DEFINITIONS AND EXPLANATIONS.

1. **THE CELESTIAL GLOBE** is constructed to represent the aspect of the heavens; all the stars are laid down on its surface according to their relative situations; and the various imaginary circles and points upon the terrestrial globe are supposed to be transferred to the celestial one. The rotatory motion of this globe, from east to west,

represents the apparent diurnal motion of the sun, moon, and stars, to a spectator supposed to be situated in the centre of the globe.

2. **THE LATITUDE AND LONGITUDE OF A STAR OR PLANET.** The latitude of a body on the celestial globe, is its distance from the ecliptic, north or south, measured in degrees on a great circle passing through the body and the pole of the ecliptic; and the longitude is the distance of the point, where the great circle cuts the ecliptic, from the first point of Aries. Latitude and longitude are referred to the ecliptic on the celestial globe, but on the terrestrial globe they are referred to the equator.

3. **THE DECLINATION AND RIGHT ASCENSION of a heavenly body.** The Declination of a body is its distance from the equinoctial, north or south, measured in degrees on a meridian passing through the body; and the Right Ascension is the distance of the point where this meridian cuts the equinoctial, from the first point of Aries. The right ascension of a body is sometimes expressed in hours, making the usual allowance of one hour of time for 15 degrees of distance.

PROBLEMS ON THE CELESTIAL GLOBE.

PROBLEM I.—*To find the right ascension and declination of the sun or of a star.*

RULE.—Bring the sun's place in the ecliptic, or the given star, to the metallic meridian; the degree over it is the declination, and the degree on the equator cut by the metallic meridian gives the right ascension.

EXAMPLES.

1. Required the right ascension and declination of Regulus, in the constellation of the Lion.

Answer. Right ascension 150° , declination $12^{\circ} 47'$ north.

Required the right ascension and declination of the following stars:

2. Capella, in the constellation of Auriga; 3. Dubhe, in the constellation of the Great Bear; 4. Aldebaran, in the constellation of Taurus; 5. Arcturus, in the constellation of Bootes.

Answers. (2.) Right ascension 76° , declination $45^{\circ} 49'$ N.

(3.) Right ascension $163^{\circ} 15'$, declination $62^{\circ} 36'$ N.

(4.) Right ascension 66° , declination $16^{\circ} 10'$ N.

(5.) Right ascension 212° , declination $20^{\circ} 3'$ N.

PROBLEM II.—*The right ascension and declination of a heavenly body being given, to find its place on the globe.*

RULE.—Bring the given degree of right ascension (or the given time of right ascension) to the metallic meridian; then under the given degrees of declination reckoned on the metallic meridian you will find the place of the body.

EXAMPLES.

1. Required the star whose right ascension is $76^{\circ} 45'$, or 5 hours 7 min., and declination $8^{\circ} 24'$ south.

Answer. Rigel, a star of the first magnitude in the constellation of Orion.

2. What stars have the following right ascensions and declinations?

	Right Ascensions.	Declinations.
2.	$261^{\circ} 30'$ or 17 h. 26 m.	$52^{\circ} 25' N$
3.	6 h. 38 m.	$16^{\circ} 29' S.$
4.	19 h. 43 m.	$8^{\circ} 26' N.$
5.	7 h. 35 m.	$28^{\circ} 26' N.$

Answers. (2.) β , a star of the second magnitude in the constellation of Draco; (3.) Sirius, in the Great Dog; (4.) Altair, in the Eagle; (5.) Pollux, the south twin.

PROBLEM III.—*To find the latitude and longitude of any star.*

RULE.—Bring the pole of the ecliptic to the metallic meridian; fix the quadrant of altitude over the pole, and move the quadrant till its edge comes over the star; then the degree of the quadrant over the star is the latitude, and the number of degrees between the edge of the quadrant and the first point of Aries, reckoned on the ecliptic, is the longitude.

EXAMPLES.

1. What is the latitude and longitude of Aldebaran, in the constellation of Taurus?

Answer. Latitude $5^{\circ} 28' S.$, longitude 2 signs $6^{\circ} 53'$.

2. What is the latitude and longitude of Pollux, in the constellation of Gemini?

Answer. Latitude $6^{\circ} 30' N.$, longitude 3 signs 21° .

PROBLEM IV.—*The day and hour, and the latitude of the place being given, to place the celestial globe so as to represent the appearance of the heavens at that place and time.*

RULE.—Place the axis of the globe north and south by the compass; rectify the globe for the latitude of the place; bring the sun's place in the ecliptic to the metallic meridian; set the hour circle to XII.; turn the globe till the index of the hour circle points to the given hour of the day; then in this position the stars figured on the globe will exactly correspond with the actual appearance of the stars in the heavens.

PROBLEM V.—*The day and hour, and the latitude of the place being given, to find what stars are rising, setting, and culminating.*

RULE.—Rectify the globe for the latitude of the place; bring the sun's place to the metallic meridian; put the hour circle to XII.; turn the globe till the hour circle indicates the given hour of the day; then all the stars on the eastern semicircle will be rising, those on the western semicircle will be setting, those under the metallic meridian will be culminating, or in their southing, and those stars above the wooden horizon will be visible at the given time and place.

To determine those stars which never set. Turn the globe on its axis; then those stars which do not go below the wooden horizon never set at the given place.

EXAMPLES.

1. To find the constellations which are rising, setting, and culminating, on the 20th of January, at 2 o'clock in the morning, at London.

Answer. The constellation of Lyra, &c., are rising; Andromeda, &c., are setting; and the Great Bear, &c., are on the meridian.

2. To find the stars which are rising, setting, and culminating, on the 8th of February, at 9 o'clock in the evening, at London.

Answer. A star, in the Northern Crown, is rising; Arcturus, in Bootes, is a little above the horizon; Sirius is on the meridian; Markab, in Pegasus, a little below the western horizon.

PROBLEM VI.—*To find the time when any heavenly body will rise, come to the meridian, and set, on a particular day, at any given place.*

RULE.—Rectify the globe for the latitude of the place; bring the sun's place in the ecliptic to the metallic meridian; set the hour circle to XII.; turn the globe till the given star* comes to the eastern edge of the wooden horizon; then the hour circle will show the time of rising: now turn the globe till the star comes to the metallic meridian, and the hour circle will show the time of its culmination or southing: lastly, turn the globe till the star comes to the western edge of the wooden horizon, and the hour circle will show the time of setting.

EXAMPLES.

1. At what time will Arcturus, in the constellation of Bootes, rise, culminate; and set, at London, on the 7th of September?

Answer. Arcturus will rise at about a quarter past 7 in the morning, culminate at a quarter past 3 in the afternoon, and set at three quarters past 10 at night.

2. At what time will Aldebaran, in the constellation of Taurus, rise, &c., at Edinburgh, on the 26th of November?

Answer. It rises at about half-past 4 in the afternoon, &c.

PROBLEM VII.—*The day of the month, the latitude of the place, and the altitude of a star, being given, to find the hour of the night.*

RULE.—Rectify the globe for the latitude of the place; bring the sun's place in the ecliptic to the metallic meridian; set the hour circle to XII.; screw the quadrant of altitude to the zenith, and turn it to that side of the meridian on which the star was observed; move the globe and the quadrant till the star is on the degree of the quadrant equal to the given altitude; then the hour circle will show the hour required.

* The place of a planet on the globe must be found by Prob. VIII.

EXAMPLES.

1. At Rome, on the 2d of December, the star Capella, in the constellation of Auriga, was observed to be 42° above the horizon and west of the meridian; required the hour.

Answer. Five o'clock in the morning.

2. At London, on the 29th of December, the star Deneb, in the tail of the Lion, was found to be 40° above the horizon, and east of the meridian; required the hour.

Answer. About a quarter past 2 o'clock in the morning.

PROBLEM VIII.—*Given the year, and the day, to find the place of a planet on the globe.*

RULE.—Bring the sun's place in the ecliptic to the metallic meridian; set the hour circle to XII.; find in the Nautical Almanac the time when the planet passes the meridian on the given day, and turn the globe till the index of the hour circle points to the hour thus found; find, in the Almanac, the declination of the planet for the same day; then under this declination, found on the metallic meridian, is the place of the planet.

ASTRONOMY.

OBJECTS OF ASTRONOMY.—GENERAL VIEW OF THE HEAVENS.

1. ASTRONOMY is that science which treats of the heavenly bodies—the sun, the moon, and the stars.

THE STARS.

2. When we look at the heavens, on a clear night, they appear to us like a vast dome, or concave hemisphere, in which the stars shine like so many brilliant gems of light. The point directly over our heads is called the **ZENITH**, and the line where the sky and the earth appear to meet is called the **HORIZON**. The **NADIR** is that point in the heavens which is opposite to the zenith—that is, it lies directly below our feet. Thus in *fig. 1*, let *cnes* represent the earth, and *c* the place of a person looking at the stars; then *z* is his zenith, *n* his nadir, and *h r* his horizon; *h z r* is the hemisphere, or half sphere, of stars which are visible to him, and *n d e* the opposite hemisphere, which would be visible to a spectator at *e* on the opposite side of the earth.

In the day-time we do not see the stars on account of the superior light of the sun; just in the same way as we should not see the flame of a candle, at the distance of a few hundred yards from us, when the sun is shining; but with a powerful telescope the stars can be seen at any time of the day.*

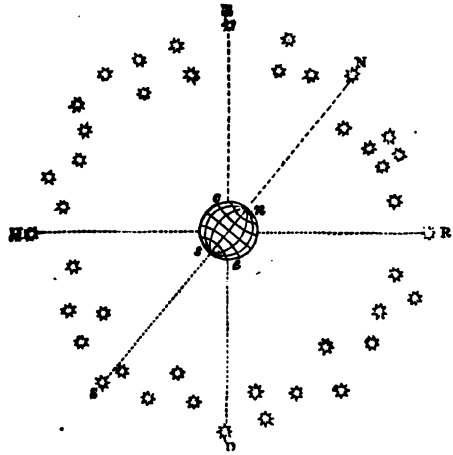


Fig. 1. The Stars.

CARDINAL POINTS.

3. If you look towards the sun at noon, your face is directed to the south; your back is towards the north; the east is on your left hand; and the west is on your right. These four points in the horizon are called the **CARDINAL POINTS**. Your shadow at noon is shorter than it is at any other time of the day, because the sun has then attained his

* See Exercises, p. 64.

greatest elevation above the horizon. The sun rises towards the east, and sets towards the west. At noon the sun is said to be on the **MERIDIAN**; and the time which elapses between his leaving the meridian, and returning to it again, is called a *solar day*.*

DIURNAL MOTION OF THE HEAVENS.

4. If we look attentively at the stars, in a cloudless night, we shall see one star after another rising above our horizon in the east, and star after star *setting* or sinking beneath our horizon in the west. A little further observation will show us that the whole visible heavens appear to turn from east to west, about a certain little star, considerably elevated, called the *polar-star*; and that a complete revolution is made in the course of every day. Now this *apparent* motion of the heavens, as we shall afterwards see, is really produced by the revolution or turning of the earth from west to east, round a line or axis, which we may conceive to be drawn through the centre of the earth and the polar-star. This is called the diurnal motion of the heavens, because it is performed in the course of a day. In *fig. 1*, *N* represents the north polar-star, *NS* the line round which the heavens appear to turn, or the line round which the earth really turns.

MAGNITUDE OF THE STARS.

5. In a clear night about two thousand stars may be seen with the naked eye, but with a small telescope many millions may be observed. The stars appear to us of different sizes and degrees of brightness: the largest and brightest are said to be of the first magnitude; the next in order, of the second magnitude; and so on to the sixth magnitude, which comprises those very small stars which are just visible to the naked eye. There are only eleven stars of the first magnitude, in our hemisphere, and six in the southern or opposite hemisphere. There are about fifty of the second magnitude visible to us, and not less than one hundred and twenty of the third magnitude.

FIXED STARS AND PLANETS.

6. Nearly all the stars which we see are fixed, that is to say, they do not change their distances from one another, but always retain their relative positions. Some of the stars, however, do not always remain in the same place, but move among the **FIXED STARS**: these stars are called **PLANETS**.

The fixed stars are also distinguished from the planets by having a more twinkling sort of light; and viewed through a telescope, the planets look like little luminous globes, while the stars simply appear like brilliant points of light without any appreciable size.

CONSTELLATIONS.

7. The ancient astronomers, for the convenience of reference, divided the fixed stars into constellations, or groups of stars, giving to them names of animals and other things,

* See Exercises, p. 69.

to which they imagined the outline of each group had some resemblance. The most striking of the constellations is that of the GREAT BEAR, which is commonly known by the name of CHARLES'S WAIN, or wagon. The form of this constellation is shown in *fig. 2*, where the four stars *a, b, c, d*, are supposed to represent the body of the wagon, and the remaining three the horses. The two stars *b, a*, forming the back of the supposed wagon, are called THE POINTERS, for if a line be drawn through them, it will very nearly point to the polar-star *n*. If a line be drawn from the star *e*, leaving *v* a little to the left, it will pass through a very brilliant star *A*, called ARCTURUS, which is the principal star in the constellation of BOOTES. The names of the different con-

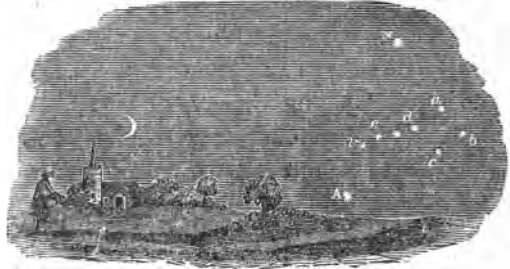


Fig. 2. Constellation of the Great Bear.

stellations may be readily acquired by looking at a celestial globe, which is constructed to represent the aspect of the heavens. These constellations always present the same appearance: the hoary-headed man, tottering on his grave, as he takes, it may be, a last look at Charles's Wain, well remembers that it presented the same aspect when he first gazed upon it in the joyous days of his childhood.

Many of the stars have received names,—such as DUBHE, the upper star of the Pointers; ARCTURUS, in the constellation of Bootes; CAPELLA, in the constellation of Auriga the Wagoner, &c.

SIGNS OF THE ZODIAC.—THE ECLIPTIC.

8. There is a remarkable class of constellations, encircling the heavens like a band or belt, in which the planets always appear to move; this belt of stars contains twelve constellations, which are called THE SIGNS OF THE ZODIAC. The sun also appears to us to make a complete revolution in the heavens, in the course of a year, through the different constellations of the Zodiac. This apparent path of the sun in the heavens is called THE ECLIPTIC; the constellations of the Zodiac, therefore, mark out the ecliptic in the heavens. The term *zodiac* means animal, and this apparent path of the sun was, no doubt, so called on account of the names given to the various constellations composing it. The Zodiac is divided into twelve signs, to correspond to the twelve months of the year. The following table gives the names of the signs of the Zodiac, with the marks or symbols which are put for them.

Names of the Signs of the Zodiac.

Aries...the Ram..... ♈	Leo....the Lion..... ♌	Sagittarius...the Archer.... ♐
Taurus...the Bull..... ♉	Virgo...the Virgin..... ♍	Capricornus the Goat..... ♐
Gemini...the Twins.... ♊	Libra...the Balance.... ♎	Aquarius...the Waterman... ♒
Cancer...the Crab..... ♋	Scorpio...the Scorpion.... ♏	Pisces.....the Fishes..... ♓

GENERAL PRINCIPLES OF ASTRONOMY.

9. In the study of astronomy, it is, above all things, necessary that we should reason upon appearances, and that we should allow the first rude notions, derived from the senses, to be corrected by the judgment. As these remarks are essential to a right appreciation of our methods of exposition, it will be instructive to elucidate them by taking one or two familiar cases.

The cross at the top of St. Paul's Cathedral *appears* not longer than a walking-stick, whereas its length is *really* greater than the elevation of an ordinary house. Here, by taking into account the distance of the cross from us, we are able to assign a reason for its apparent smallness. In precisely the same way, the moon appears to us scarcely larger than a man's face, but when it is considered that she is many thousands of miles from us, we should be prepared for adopting the fact that she is a world not much smaller than the earth on which we live. In like manner, we should be led to expect that the planets, which, owing to their still greater distances from us, appear like little balls of light, are in reality vast globes; many of which are considerably larger than our earth.

When we are moving in a railway carriage, we should from appearances believe, if our reason did not correct this belief, that the houses and trees were moving, and that we were standing still. In like manner, we should be prepared to question the truth of the first impression of our senses, when we are led to imagine that the whole of the heavens turn round us in every twenty-four hours, and to ask ourselves, Is it not more rational to suppose that this apparent motion is produced by the actual rotation of our earth itself? The science of astronomy has established many principles which are at variance with the first rude notions derived from mere appearances. The following general principles deserve especial attention:

Our earth has the form of a globe; it turns or rotates upon its axis once every twenty-four hours, and thus gives rise to the apparent diurnal or daily motion of the heavens; it also moves round the sun, in the course of a year, which occasions the apparent motion of the sun in the ecliptic. The planets are worlds like our own; and they, together with our earth, revolve round the sun as the common center of attraction, in different paths or orbits; they also derive their light and heat from him. The sun, and all the planetary bodies which move round him as a center, compose what is called the SOLAR SYSTEM. The fixed stars, which are at immense distances from us, are suns with their respective systems of unseen worlds revolving round them, probably similar to the solar system.

THE SOLAR SYSTEM.

10. THE solar system consists of the sun, in the center, round which all the planetary bodies revolve.

The Primary planets move round the sun from west to east, in nearly circular orbits or paths, lying nearly in the same plane, or flat surface,—that is, in the plane of the ecliptic; and rotate, or turn round on their axes, in the same direction. Some of the planets have moons or satellites revolving round them. The names of the planets, in the order of their distances from the sun, are MERCURY, VENUS, the EARTH, MARS, JUPITER, SATURN, URANUS, and NEPTUNE; together with about fifty-two small planets called ASTEROIDS, which move in orbits lying between Mars and Jupiter. These are called primary planets: there are also 20 moons or satellites which are called secondary planets, because they revolve round their respective primaries in the same manner as the latter revolve round the sun. The moon is the satellite to the earth; she completes a revolution round the earth in the course of every lunar month. Jupiter has four satellites; Saturn eight; Uranus six; and Neptune one. Besides these, there is another class of bodies, which revolve round the sun, called COMETS; many have blazing tails, and all move in very eccentric orbits.

The solar system, as just described, was first taught by Pythagoras, an eminent Greek philosopher, who lived about 500 years before the time of Christ. But it was soon after disregarded, and various false systems were taught in its place, until about 300 years ago, when Copernicus revived the true system which had been discovered by the great Pythagoras.

The planets, with the other bodies composing the solar system, will be more fully described after we have considered the different motions, &c., of the earth and the moon.

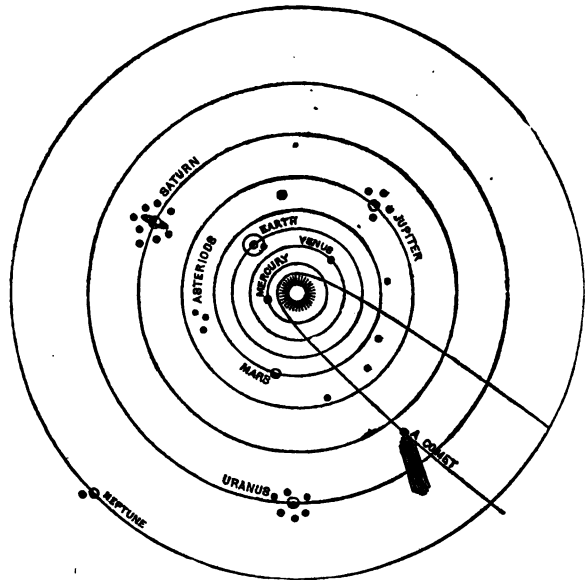


Fig. 3. Solar System.

THE EARTH AND ITS MOTION.

FORM AND SIZE OF THE EARTH.

11. The earth has the form of a *globe*; that is, it is like a ball or orange. This is proved by various facts. The following are given as being the most simple:

(1.) *Navigators have sailed round the Earth.*

If a ship sail constantly in the same general direction, either eastward or westward, she will arrive at the same place from which she set out. Now, if the earth were an unbounded plain, or flat surface, the further the ship sailed, the further she would get from the point of departure. **MAGELLAN** was the first mariner that sailed round the world, but **COLUMBUS** was the first that made the attempt.

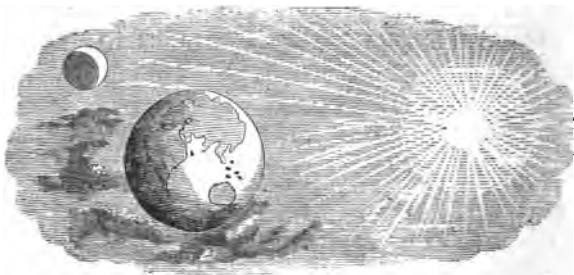


Fig 4. The Earth in space.

The earth, then, is a great globular mass of matter, without any fixed point of support.

(2.) *The Hull of a Vessel sinks as she leaves the Shore.*

12. When a vessel leaves the shore, at a little distance a portion of the hull is observed to sink; a little further, the hull is lost to the sight; at a greater distance, the lower sails disappear: until at length, only the upper sails are seen in the *horizon*, or the line where the earth and sky appear to meet. But if we now ascend a high tower, we should get sight of the hull again. Now, if the earth were a flat surface, we should always see the hull at the same time that we see the top-sails.



Fig. 5. Rotundity or roundness of the Earth.

(3.) *The Earth always appears of a Circular Shape.*

13. The *rotundity* or roundness is such, that a man six feet high, standing upon the sea-shore, would see a little boat when its distance from him does not exceed three miles; but if he were elevated twenty-four feet, the boat would be seen at the distance of six miles; and if he were elevated fifty-four feet, the boat would be seen at the dis-

tance of twenty-seven miles, and so on: the distance at which the boat would be seen increasing with the elevation of the observer. In all these cases, the man's view is bounded by a *circular horizon*. Now there is no body but a globe, that will always appear of a circular shape when viewed at different distances.

Observe! at whatever distance I look at this little globe, it always appears to have a circular shape; and moreover, the further it is removed from my eye, the greater is the extent of surface that I see. Mr. Wise, when he goes up with his balloon, will see more of the earth's surface than we can, even though we should be on the top of Bunker Hill monument; and whatever may be his height above the earth's surface, he will always find that it presents a circular shape. When he has attained his greatest elevation, the largest hills and trees will appear to him just like the little irregularities which we see upon the surface of an orange.

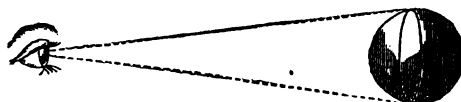


Fig. 6. A globe always appears round.

The Diameter of the Earth is about 8000 miles.

14. The *diameter*, or line passing through the center of the earth, is about 8,000 miles long; and as the length of the circumference of a circle is a little more than three times the diameter, it follows, that the length of a line going round the earth, or the *circumference*, is about 25,000 miles. A railway train, moving with the speed of 50 miles per hour, would go round the earth in about 500 hours, or about three weeks, supposing there were no obstructions to the motion. This will give us some idea of the great size of the earth.

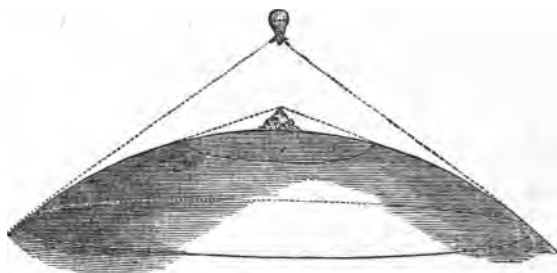


Fig. 7. The Earth always appears round.

DIURNAL MOTION OF THE EARTH.

15. The earth has two motions,—a *diurnal* or daily motion upon its axis, and an *annual* or yearly motion round the sun; that is, it turns round like a spinning-top, and at the same time moves round the sun.

Cause of Day and Night.

16. The rotatory motion, or revolution of the earth upon its axis, is the cause of day and night. When the sun shines upon our side of the earth, it is day with us, and when he shines on the opposite side, it is night with us. If you hold a globe or orange

before a candle, one-half of the globe will be enlightened, and the other half will be in the shade; and if the globe be turned round, every portion will be successively brought within the light of the candle.

The line *e, f*, separating the light and shade, is called *the circle of illumination*.

Let us suppose a little fly to be fixed on this globe; then, throughout one-half of the revolution, the creature will be in the shade, and throughout the other half,

it will be in the light. When the fly comes on the circle of illumination, it will then just begin to see the candle; and when it is passing out of the circle of illumination, on the other side, the candle will just be disappearing to it; but when it is in the middle of these two points, the candle will shine directly or perpendicularly over it, and here it will enjoy the greatest amount of light and heat from the candle. So it is with our earth;—the sun enlightens one-half of the earth at one time, the other half being in darkness. When a place just comes within the circle of *illumination*, the sun then begins to shine or rise to that place; and on the contrary, when the place is just going out of the circle of illumination, the sun will be disappearing or setting to that place; and midway between these two lines of illumination, the sun will shine directly over, or perpendicularly over the place, and then it will be noon to that place.

Now, if the earth were standing still, one-half of it would have perpetual day, and the other half would have perpetual night. But in order that the whole, or nearly the whole of the earth may be habitable, it is ordained by our all-wise and good Creator that the earth should turn round once every natural day, so that every portion might enjoy, in succession, the light and heat of the sun. This motion of the earth is called the diurnal or daily motion.

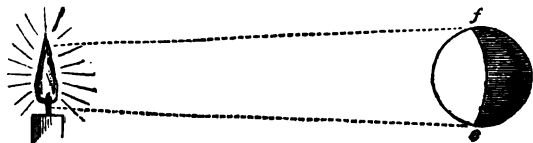


Fig. 8. Light and Shade.

Why the Sun and Stars appear to move from East to West.

17. But how, it may be asked, do we think that the sun and stars move from east to west? Just in the same way (see Art. 9) as when we are in a railway carriage we believe, if our reason were not to correct the belief, that the nearest trees and houses have a motion *contrary* to that which we really have.

In order to illustrate this still further, let *A* represent an object capable of moving round the globe *EF*, which admits of turning on its axis *o*. First let the object *A* move round the globe in the direction of the arrow shown in the figure, while the globe itself remains at rest: the object at *A* will appear in the horizon to a spectator at *E*; but as the object moves it will appear to the spectator to rise higher and higher above the horizon, until it

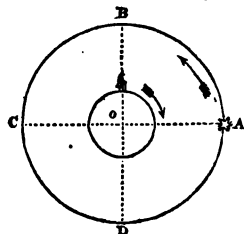


Fig. 9.

arrives at B, when it will appear in the zenith, or directly over the head of the person. Next let the globe turn round on its axis *o*, in a direction *contrary* to that in which the object moved, as shown by the arrow in the figure, while the object A stands still. The apparent motion of the object, as seen by the spectator at E, will be exactly the same as before. Thus, when the globe begins to revolve, the object A will appear to the spectator E to be in the horizon; but as the globe turns round, the object A will appear to rise higher and higher above the horizon, until the spectator has turned round to F, when the object will appear in his zenith, or directly over his head. Now, if the globe turned round on its axis without any jarring motion, or without any jolting or shaking, as the earth really does, so that our spectator might be altogether insensible of his own motion, then it is plain that he would at first believe that the object had moved from A to B,—that is, from his horizon to his zenith,—in the place of having himself moved round with the globe from E to F. Thus, the *apparent* motion of the heavens, from east to west, would be produced by the *actual* rotation of the earth on its axis from west to east.

Now it would be opposed to the simplicity which we everywhere observe in the works of God, as well as at variance with the known laws of mechanics, to suppose that the sun, with many millions of worlds, most of which are vastly larger than our own, should move round our globe once in every day, when the same end could be served by our earth simply turning on its axis.*

LINES UPON THE GLOBE.

18. The earth, then, makes a complete revolution every day: the line about which it turns is called the *axis of the earth*; and the points where this imaginary axis pierces the earth's surface are called the poles. There are, therefore, two poles; the one being called the NORTH POLE, the other the SOUTH POLE. If a line be drawn round the earth, everywhere at the same distance from the two poles, it will form THE EQUATOR. If you turn a globe upon its axis, you will find that the line which we call the equator has the quickest motion, and that the poles are the only points on the surface of the globe which have no motion. In this figure, NS represents the axis of the earth, N the north pole, S the south pole, EQ the equator. The equator, therefore, divides the surface of the earth into two equal parts: the portion ENQ is called the NORTHERN HEMISPHERE, or half-sphere; and the portion EQS is called the SOUTHERN HEMISPHERE.

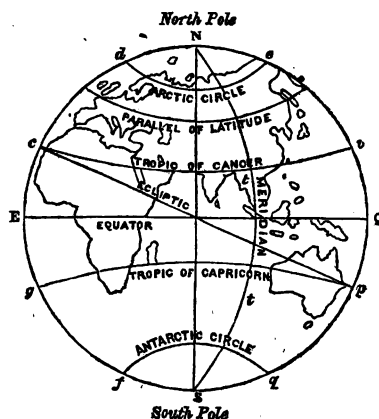


Fig. 10. The Globe.

* The rotation of the earth has recently been proved by an experiment with a long pendulum.

Circles upon the globe are divided into 360 equal parts, and each part is called a degree. A semicircle, or half-circle, will contain 180 degrees (180°). A quadrant, or quarter-circle, will contain 90 degrees (90°). The distance of the equator from either of the poles will, therefore, be equal to 90° .

Latitude and Longitude.

19. A line, *not*s, drawn between the north and south poles, is called a MERIDIAN; because, when any meridian is opposite to the sun, it is *midday*, or noon, to all places on that line. These circles will all, evidently, lie due north and south. Meridian lines are also called lines of longitude. The meridian passing through Greenwich is called the FIRST MERIDIAN, or the one to which the position of all the others is referred. The LONGITUDE of a place is its distance, in degrees, east or west, from the first meridian. Thus, America has west longitude, whereas Asia and Africa have east longitude.

20. The LATITUDE of a place is its distance from the equator. All places in the northern hemisphere have *north latitude*; and, on the contrary, all places in the southern hemisphere have *south latitude*. Thus, a place midway between the equator and north pole will have 45° north latitude; whereas, a place midway between the equator and the south pole will have 45° south latitude. London being $51\frac{1}{2}^\circ$ from the equator, has $51\frac{1}{2}^\circ$ north latitude. Lines drawn round the earth parallel to, or even with the equator, are called PARALLELS OF LATITUDE, such as *de*, *cv*, *gp*, &c. These lines are called SMALL CIRCLES, because they are less than the GREAT CIRCLES, or circles which divide the globe into two equal parts, like the equator. The use of parallels of latitude is to point out places that have the same latitude or distance from the equator. The latitude of a place will obviously be measured upon the meridian passing through the place.

21. In order to fix the exact position of a place, we must have its distances from two known lines. Thus, my position in this room will be known, when I tell you that I am twelve feet from the wall in front of me, and ten feet from the wall to the right of me. So it is with respect to the earth; when we know the distance of a place, north or south, from the equator, and at the same time its distance, east or west, from the first meridian, the position of that place becomes known. A meridian, drawn through a place, will cut the equator in a certain point, the distance of which from the first meridian, measured in degrees on the equator, will give the longitude of the place; and the distance of the place from the equator, measured in degrees upon the meridian, will give the latitude. Thus, if the meridian, passing through the place, lies 23° to the east of the first meridian, then the place will have 23° east longitude; and if the place be 40° north from the equator, the latitude will be 40° north.

22. Because the earth turns once on its axis from west to east, or describes 360 degrees in the course of twenty-four hours, it follows that the twenty-fourth part of 360° ,

or 15° , will be turned round every hour. A place, therefore, having 15° east longitude will have noon one hour before us; and a place having 15° west longitude, will have noon one hour after us. In general, we must allow an hour as the difference of time between any two places for every 15° difference of longitude. Thus, Alexandria has 30° east longitude; consequently, as many times as 15° can be taken out of 30° , so many hours will the people of this place have noon before us; that is, their noon will take place two hours before our noon.

23. By this means, seamen are enabled to find their longitude. Suppose, for example, that the pointer of the clock which they take with them, keeping Greenwich time, should be at nine o'clock in the morning, when it is noon at the place of observation; then the difference of time being three hours, the difference of longitude will be three times 15° , or 45° ; but as the place of observation has noon before us, it will consequently have 45° east longitude.

24. As the length of the parallels of latitude get shorter and shorter as they approach the pole, it follows that a degree of longitude, estimated on any parallel of latitude, is shorter than a degree on the equator. This principle is observed in the construction of maps.

The Tropics and Ecliptic.

25. If the sun were always shining perpendicularly over the equator, as in *fig. 11*, the length of the day and night would always be equal all over the globe. The sun has this position at the commencement of our spring and autumn; that is, on the 21st of March and on the 22d of September.

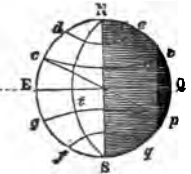


Fig. 11. The Sun at spring and autumn.

Owing to causes which will afterwards be explained, we find that during our mid-summer day the sun shines perpendicularly over a line *cv*, going round the earth $23\frac{1}{2}^\circ$ on the northern side of the equator (see *figs. 11, 12*). This line is called

THE TROPIC OF CANCER, because the sun appears to us, at this time, among a certain group of stars called the constellation of Cancer, or the Crab. Now, as the sun enlightens one-half of the globe at one time, it follows that his light must extend $23\frac{1}{2}^\circ$ over the north pole,—that is, to the point *e* in the figure; and the line *ed*, drawn round the earth parallel to, or even with the equator, is called the ARCTIC CIRCLE.

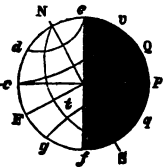
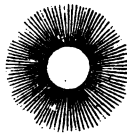


Fig. 12. The Sun at summer.

In like manner, during our mid-winter day (see *fig. 13*), the sun shines perpendicularly over a line gp , $23\frac{1}{2}^\circ$ on the south side of the equator. This line is called the TROPIC OF CAPRICORN, because the sun appears to us, at this time, among a group of stars called the constellation of Capricorn, or the Goat; and the line $f'q$ in the figure, drawn round the earth at the distance of $23\frac{1}{2}^\circ$ from the south pole, is called the ANTARCTIC CIRCLE.

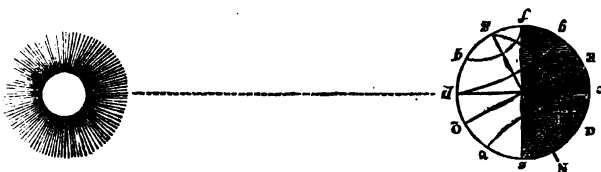


Fig. 13. The Sun at winter.

If a line cp be now drawn round the earth touching the tropics of Cancer and Capricorn, it will form the ecliptic, or apparent path of the sun throughout our year. The ecliptic is, therefore, inclined to the equator at an angle of $23\frac{1}{2}^\circ$.

The Zones on the Earth.

26. With the view of rudely marking out the climates upon the earth, its surface is divided into five zones or belts. The portion lying between the tropics of Cancer and Capricorn, is called the **TORRID ZONE**, or hot zone; for here the sun, shining almost perpendicularly upon the earth, will, in general, cause this portion to be very warm. The portion in the northern hemisphere, lying between the Tropic of Cancer and the Arctic Circle, is called the **NORTH TEMPERATE ZONE**; and the corresponding portion in the southern hemisphere, lying between the Tropic of Capricorn and the Antarctic Circle, the **SOUTH TEMPERATE ZONE**. The surface within the Arctic Circle is called the **NORTH FRIGID ZONE**, and that within the Antarctic Circle, the **SOUTH FRIGID ZONE**; because, from the slanting direction with which the sun's rays meet the surface of the earth at these regions, they are found to be, in general, very cold.

27. It is obvious that the only places on the earth, to which the sun can be vertical, are those lying within the torrid zone; and that to all such places there can be but little variation in the length of the days; whereas, within the frigid zones, the sun will shine for a certain number of days without setting, and for a corresponding number of days he will not appear above the horizon.

The Elevation of the Polar-star is equal to the Latitude of the Place.

28. To understand this, let us suppose that we are at the equator; then the polar-star will be in our horizon, being 90° from our *zenith*, or the point over our heads. Now suppose we travel 1° on a meridian line, or directly towards the north pole, then the polar-star will appear elevated 1° above our horizon; by traveling 2° , the polar-star will appear elevated 2° ; half way between the equator and the pole, our distance from the equator will be 45° , and then the polar-star will appear to us elevated 45° , and so on.

Thus it is that the elevation of the polar-star gives us the latitude of the place. By this means, navigators sailing on an expanse of ocean can find the latitude of the place where they are.

Measurement of the Earth.

29. The same course of reasoning will show how a *degree on the earth's surface* is measured. At London, the elevation of the polar-star is about $51\frac{1}{2}^{\circ}$; now if we travel due north until we find its elevation to be $52\frac{1}{2}^{\circ}$, we shall have traveled over 1° , or the 360th part of the earth's circumference; and if this distance be accurately measured, it will be found to be about $69\frac{1}{2}$ miles, which is consequently the length of a degree. The whole circumference of the earth will therefore be about 360 times $69\frac{1}{2}$ miles, or, in round numbers, 25,000 miles.

It must, however, be observed that the earth is not an *exact* sphere, for it has been found that the length of a degree measured near the poles, is greater than it is at the equator; thereby showing that the earth is a little flattened at the poles, so that the diameter passing through the equator is about 26 miles greater than the diameter passing through the poles.

ANNUAL MOTION OF THE EARTH.—CAUSE OF THE SEASONS.

30. Besides the rotary motion of the earth upon its axis, we have said that it moves round the sun in the course of a year, in a path, or *orbit*, which is nearly circular. This annual motion, combined with the unchanging direction, or *parallelism*, of the earth's axis, is the cause of the seasons. Let the globe (described at page 37) be carried round a candle (covered with a glass shade about the same size as the globe), at the same time that it is kept spinning upon its axis; then we shall have a tolerably correct exhibition of the twofold motion of the earth, viz., its *diurnal* or daily motion on its axis, and its *annual* motion round the sun. The path in which the globe is moved will represent the *orbit* of the earth, and a level or even surface going through this path will represent the *plane* of the earth's orbit. Again, let our little globe be carried round the candle, with its axis perpendicular or upright to the plane of the orbit; then it will be seen that the circle on the globe separating the light and shade passes through the poles throughout the whole revolution. This position of the axis, therefore, will not account for the changes of the seasons.

Let the globe be now carried round the candle with the axis constantly inclined to the plane, or surface of the table, at the same angle; then, in every position of the globe, it will be seen that the axis always lies in the same direction, or that it is always parallel to itself.

Let the globe have the position *c* in the figure, where the axis is inclined toward the sun, so that a rod extended from the candle, representing the sun, shall be perpen-

dicular to the Tropic of Cancer, at *e*; then, as the light will extend over 90° every way from *e*, the circle *ef*, which separates the light and shade, will pass $23\frac{1}{2}^\circ$ over and beyond the north pole, and therefore, during the revolution of the globe on its axis, the whole of the North Frigid Zone will be enlightened; and on the contrary, the whole of the South Frigid Zone will be in darkness. In order to illustrate this, suppose a little fly were placed upon the Arctic Circle, then, throughout a whole revolution, the creature will not have gone without the light of the candle; and on the contrary, let it be placed upon the Antarctic Circle, then throughout a whole revolution it will not have come within the light at all. It will also be seen, that all places in the northern hemisphere will be longer in the circle of light than in the circle of darkness; and on the contrary, all places in the southern hemisphere will be longer in the circle of darkness than in the circle of light: that is, in the former hemisphere, the days, as in our summer, will exceed twelve hours; while in the latter hemisphere, the day will be less than twelve hours. Whereas, exactly on the equator, the days will not alter in their length. This position of the globe corresponds to our midsummer, or 21st of June.

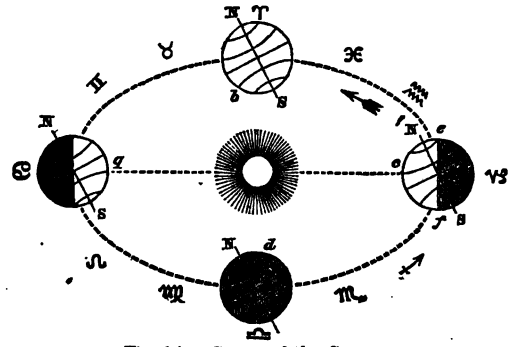


Fig. 14. Cause of the Seasons.

Constantly keeping the axis pointing in the same direction, let the globe be brought to the position *b* of the figure, where the axis neither inclines to the sun nor from the sun: now the light will fall perpendicularly on the equator; the circle separating the light and shade will pass through the poles, and therefore the days and nights will be equal all over the globe. This position corresponds to our AUTUMNAL EQUINOX, the 22d of September, or to that time in autumn when the length of the night equals the length of the day. Still keeping the axis pointing in the same direction, let the globe be now brought to the position *g*, where the north pole inclines away from the sun; here the *reverse* of what was observed in the first position *c* will now take place. The sun will shine perpendicularly over the Tropic of Capricorn, and the southern hemisphere will enjoy more of the sun's light and heat than the northern. This position corresponds to our mid-winter, the 21st of December, and then our days will be at their shortest.

Let the globe now be brought to the position *d* of the figure; then, here again, the axis neither inclining to the sun nor from the sun, the days and nights will be equal, as at the autumnal equinox. This position corresponds to our VERNAL OR SPRING EQUINOX, the 20th of March.

When the globe is brought to the position *c*, it has made a complete revolution in

its orbit, and the period corresponds to our natural year, or 365 days, 5 hours, 48 minutes, and 51 seconds. Particular attention should be given to the circumstance that the axis of the globe, throughout the whole revolution, has maintained its parallelism.

31. While the earth thus performs a revolution in its orbit, the sun will *appear* to us to make a complete revolution in the heavens, through the different constellations in the *zodiac* or belt of stars. Thus, in our midsummer, the sun will be referred to the sign ϖ , or constellation of Cancer; in our autumnal equinox, to the sign of Libra, or φ ; in our midwinter, to the sign of Capricornus, or $\var�$; and in our vernal equinox, to the sign of Aries, or γ .

32. Thus, the changes of the seasons, as well as the apparent annual motion of the sun, are perfectly explained, by supposing the earth to move round the sun. But why, it may be asked, do we, in opposition to the first impression of our senses, believe that the earth moves instead of the sun? Just for the same reason that we infer that the *apparent* diurnal revolution of the sun round the earth is produced by the actual rotation of the earth on its axis in every twenty-four hours. (See Art. 17.)

33. The distance of the earth from the sun is about ninety-five millions of miles. In order to form some conception of this immense distance, let us suppose a body to move from the earth to the sun with the speed of one of our railway carriages, (50 miles per hour), then it would take about 220 years to arrive at the sun.

THE MOON.

34. The diameter of the moon is about 2000 miles, or about one-fourth the diameter of the earth; she performs a revolution round the earth in 27 days, 7 hours, 43 minutes, in an orbit whose radius is about 240,000 miles, or about 60 times the earth's radius. The moon always presents the same face to us; hence it follows, that she must turn round on her axis in the same time that she revolves round the earth.

MOUNTAINS AND CAVITIES ON THE MOON.

35. When the moon is viewed through a telescope, various spots, of different degrees of brightness and depth of shade, are observed on her surface. The darkest portions are caused by deep cavities and valleys; those of a lighter shade by the shadows of high mountains; and the brightest spots are the illuminated tops of the mountains, which look like the craters of volcanoes. The heights of many of the mountains on the moon have been calculated from the lengths of the shadows which they cast. The loftiest of them are about four miles high. The moon has no clouds, nor have any decided indications of an atmosphere been observed. It therefore seems improbable that living beings, such as we are, can exist there.

PERIODICAL AND SYNODICAL MONTH.

36. Like the sun and planets, the moon, in consequence of her revolution round the earth, has an apparent motion from west to east among the stars of the zodiac. Her motion among the stars is so rapid, that it may be readily perceived by a few hours' observation on any moonlight night. As already stated, she makes a complete revolution in the heavens in 27 days, 7 hours, 43 minutes; that is to say, she takes this time in passing from a star to returning to the same star again;—this is called her **PERIODICAL MONTH**: but the time from new moon to new moon again, is rather longer than this, in consequence of the motion of the earth in its orbit. The time from new moon to new moon is 29 days, 12 hours, 44 minutes; this is called the **SYNODICAL MONTH**.

Let *s* (*fig. 15*) represent the sun; *E* the earth; *AB* a part of its orbit; *MO* the orbit of the moon round the earth; *M* her position at new moon, which is in a line drawn from the earth to the sun. Now if the earth had no motion, the moon would move round in her orbit and return to the position *M* in a periodic month; but while the moon is describing a revolution, the earth will have moved over about the twelfth part of its orbit, suppose from *E* to *e*. The moon will then be at *n*, where *en* is drawn parallel to *EM*, and she must therefore move over an additional portion, *nm*, of her orbit before she comes again in the line *es* joining the earth and the sun. This additional portion being about the twelfth part of her whole orbit, occasions the time of the synodical revolution to exceed the periodical by rather more than two days. This is well illustrated by the relative motions of the hour and minute hands of a watch: at 12 o'clock the hands are together, but before they can come together again the minute hand must move over a whole revolution and rather more than the twelfth part of another one.

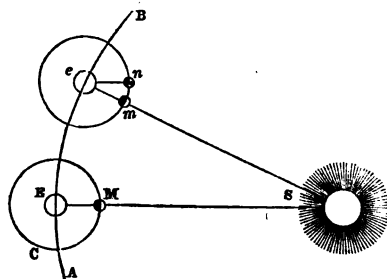


Fig. 15. Periodical and Synodical month.

THE MOON'S FACES.

37. The sun always enlightens one-half of the moon; but as her enlightened hemisphere is always directed towards the sun, she presents different faces of illumination to us as she moves in her orbit. Sometimes we see the whole of her enlightened disk, sometimes only a small portion of it, and at other times none at all.

Let *E* represent the earth (see *fig. 16*); *s* the sun; and *a, b, c, d, e, f, g, h*, the moon in different parts of her orbit, having her enlightened hemisphere always turned toward the sun. The little circles, outside of the line representing the moon's orbit, show the moon's faces at the respective positions, as seen by an observer on the earth.

When the moon is at *a*, in a line with the earth and the sun, the dark face of the moon is turned toward the earth: the moon is then at her **CHANGE**, or she is called **NEW MOON**. She is also at this time in **CONJUNCTION** with the sun.

At *b* a small portion of her enlightened hemisphere is turned toward the earth, and she then appears **HORNED**.

At *c* one-half of her enlightened hemisphere is turned toward the earth, and she then appears as **HALF MOON**. This takes place at the end of her first quarter, or at her **QUADRATURES**.

At *d* about three-quarters of her enlightened hemisphere is visible to us, and she is then said to be **GIBBOUS**.

At *e*, when she has completed one-half of her revolution, the whole of her enlightened hemisphere is visible to us, and she is then **FULL MOON**. In this position she is said to be in **OPPOSITION** to the sun. If the plane of the moon's orbit had exactly coincided with that of the earth's, she would have been invisible to us at this period, for, in this case, the earth would have obstructed the sun's light; but it so happens that she is mostly either above or below the line connecting the earth and the sun, and hence it is that we usually see the whole of her enlightened face. This will be better understood when we come to consider the subject of eclipses.

At *f* she is gibbous, at *g* half moon, at *h* horned, and at *a* she again becomes invisible.

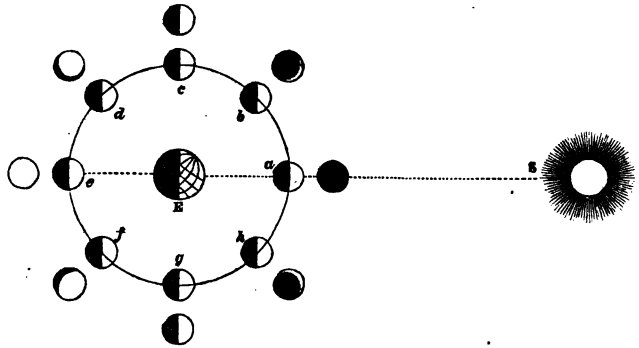


Fig. 16. The Moon's faces.

ECLIPSES.

38. An eclipse of the sun is called a **SOLAR ECLIPSE**, and that of the moon a **LUNAR ECLIPSE**. When the moon comes between the earth and the sun his light is obstructed, and an eclipse of the sun is produced; and an eclipse of the moon takes place when the earth is between the sun and the moon. Hence it is that eclipses of the moon can only occur at her full, or when she is in opposition, and eclipses of the sun at her change, or when she is in conjunction; moreover, the three bodies must be in, or nearly in, the same straight line. Now if the moon's orbit were in the same plane as the ecliptic, or path of the earth, then the sun would be eclipsed at every new moon, and the moon would be eclipsed at every full moon. But as her orbit is a little inclined to the earth's, she is mostly either above the ecliptic, or below it, when she is in opposition and conjunction. The points where the moon's orbit cuts the plane of

the ecliptic are called the *NODES*; hence it follows that eclipses can only take place when the moon happens to be in, or near, one of the nodes at the moment she is in opposition or conjunction. In the course of a year there may be seven eclipses of the sun and moon: five of the sun and two of the moon, or four of the sun and three of the moon. Lunar and solar eclipses differ very much from each other in certain respects. A lunar eclipse may be seen at the same time by all persons to whom the moon is visible; whereas a solar eclipse may be seen by one person and not by another. Again, an eclipse of the sun can never last more than eight minutes, whereas an eclipse of the moon frequently continues for more than two hours.

Eclipse of the Moon.

39. If the whole disk or face of the moon is immersed in the shadow cast by the earth, then the eclipse is said to be *TOTAL*; and the eclipse is said to be *PARTIAL* when only a part of the disk is obscured.

In *fig. 17*, a total eclipse of the moon is shown: *s* represents the sun; *EE* the earth; *AB* the moon's orbit round the earth; *EEV* the conical shadow cast by the earth; *M* the dark body of the moon totally immersed in this shadow.

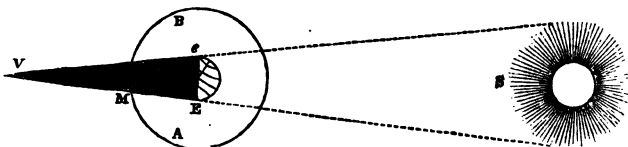


Fig. 17. Total Eclipse of the Moon.

It is always observed that the edge of the earth's shadow on the face of the moon is circular. Now this proves that the earth is a globe; for no body but a globe will always cast a circular shadow. Take an orange and hold it on a level with the flame of a candle: observe the shadow which is cast upon a sheet of paper held at different distances from the orange.

Eclipse of the Sun.

40. A total eclipse of the sun takes place at those places on the earth's surface which are immersed in the moon's shadow. *Fig. 18* represents a total eclipse of the sun: where *s* represents the sun; *EE* the earth; *AB* the moon's orbit; *M* the moon exactly in a line between the sun and the earth; *cnao* the moon's shadow cast upon a small portion of the earth at *ao*; this dark shadow is called the *UMBRA*. The sun will appear totally eclipsed to persons living within *ao*; but to

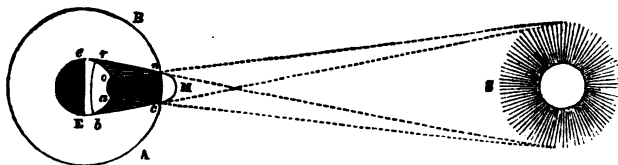


Fig. 18. Total Eclipse of the Sun.

persons living without this portion—that is, between ao and ee —the sun will be visible. Between ao and br the sun will be partially obscured. This portion of the shadow is called the **PENUMBRA**, because it is not so dark as the umbra, or the portion in the full shadow.

Within the umbra, therefore, a total eclipse takes place ; whereas within the penumbra the sun is only partially eclipsed.

Annular Eclipse.

41. If the conical shadow of the moon does not reach the earth, then an **ANNULAR ECLIPSE** will take place to all persons immediately below the vertex of the moon's shadow,—that is, the moon will appear like a black spot upon the sun, surrounded by a ring of light. Here the vertex of the moon's conical shadow does not reach the earth at a ; so that a spectator at a will see the moon like a dark spot nearly covering the sun's disk.

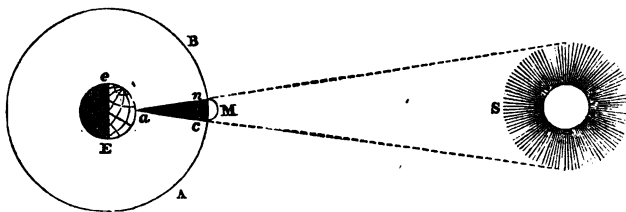


Fig. 19. Annular Eclipse.

THE SUN AND PLANETS.

42. Having described the motions of the earth and the moon, we shall now treat of the sun, with the other bodies composing the solar system. (See Art. 10.)

43. The planets are opaque bodies ; that is to say, they do not emit any light of their own, but merely shine with the light borrowed from the sun. This is proved by means of the telescope, which shows that they present faces, similar to the moon's, having their enlightened sides always turned toward the sun.

44. The planets are divided into inferior and superior. Those which revolve *within* the earth's orbit are called **INFERIOR PLANETS**, and those which revolve *without* it are called **SUPERIOR PLANETS**. Thus Mercury and Venus are inferior planets, and Mars, Jupiter, Saturn, Uranus, and Neptune, together with the Asteroids, are superior planets. (See fig. 3.)

APPARENT MOTIONS AND APPEARANCES OF THE PLANETS EXPLAINED.

45. Viewed from the sun, as the great center of the solar system, the planets would appear to move round him in regular order and progression. But the case is very dif-

ferent when we view their motions from the earth, which also moves round the sun. At one time they appear to have a **PROGRESSIVE** or direct motion—that is, from west to east; then they appear **STATIONARY**, or without any apparent motion; and at other times they appear to have a **RETROGRADE** motion—that is, from east to west. They are sometimes in **CONJUNCTION** with the sun, and then they are generally lost in his superior light; and some of them (the superior planets) appear in **OPPOSITION** to the sun—that is, in the opposite point of the heavens.

In order to form a familiar idea of these motions, conceive yourself placed in the center of a horse-ring: the horse, as he moves round you, will appear to move in a regular and progressive manner. Now conceive yourself to be placed without the ring; then the motion of the horse appears no longer regular: at one time he appears to move, say from right to left; then for a moment he appears as if he were stationary, and afterward he appears to move from left to right, and in two points of his path he appears in conjunction, or, as it were, in the same place with the man in the center of the ring. These apparent motions of the horse give a true representation of the apparent motions of the two inferior planets, Mercury and Venus.

Opposition and Conjunction of the Planets.

46. That Mercury and Venus are inferior planets, is proved by their crossing the sun's disk like a black spot, thereby showing that they must revolve between us and the sun; whereas Mars and the other superior planets never do so. Moreover, Mercury and Venus never appear in opposition; whereas Mars and the other superior planets appear in opposition as well as in conjunction.

In *fig. 20*, let *s* represent the sun; *e* the earth; *v* an inferior planet; and *m* a superior one. At *m* and *v* both planets appear in conjunction to a spectator on the earth; but at *m* and *v* the superior planet, *m*, is in opposition, while the inferior planet, *v*, is in conjunction; and at this position it will sometimes appear like a black spot crossing the sun's disk. This is called the **TRANSIT** of Venus, or Mercury, as the case may be. Thus while the superior planets never cross the sun's disk, the inferior ones never appear in opposition.

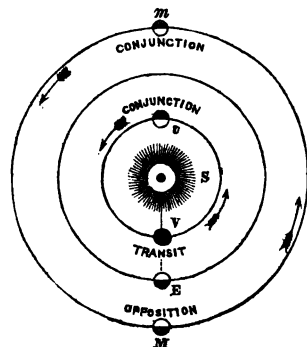


Fig. 20. Conjunction and Opposition.

Apparent Motions of Venus.

47. We shall now illustrate the cause of the apparent motions and phases of the planets by a reference to the planet Venus.

In *fig. 21*, let *s* represent the sun; *e* the earth; *abcdefgh* the different positions of

Venus in her orbit; ea and gf tangent lines drawn from the earth to the orbit of Venus. From a to b the planet Venus appears **STATIONARY**; that is, for a time she neither appears to move toward the west nor toward the east. In this position she has attained her greatest westerly distance, or *elongation*, from the sun. From b to f her motion is **DIRECT**—that is, she appears to move among the stars from west to east. From f to g she is again **STATIONARY**; and from g to a her motion is **RETROGRADE**,—that is, she appears to move from east to west. At h , in a line with the earth and sun, a transit takes place. Thus in making an apparent revolution from a round the sun she is first stationary, then she has a direct motion, next stationary, and, finally, she has a retrograde motion.

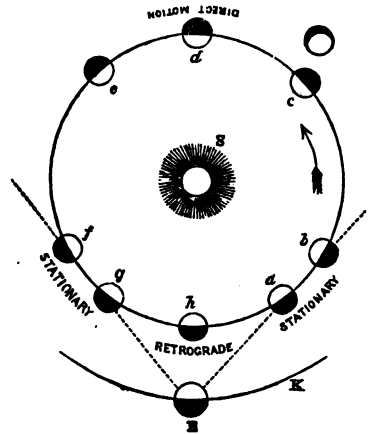


Fig. 21. Apparent motions of Venus

Phases of Venus.

48. Between h and a (see *fig. 21*) her enlightened hemisphere appears to us like a *horned moon*; at a and b she presents the appearance of a *half-moon*; at c *gibbous*; and at d *full-moon*; and so on. It is plain, that if Venus had shone with her own light, she would always have appeared perfectly round to us.

Morning and Evening Star.

49. When Venus appears to the west of the sun, that is, from d to h (see *fig. 21*), she is the evening star, for then she shines in the western sky at sunset; and on the contrary, when she appears to the east of the sun, that is, from h to d , she shines in the eastern sky before sunrise.

COMPARATIVE SIZE AND APPEARANCE OF THE PLANETS.

50. The diagram here given exhibits the comparative size and appearance of the principal planets in the solar system.

Jupiter is the largest of all the planets;—his diameter is about 11 times the diameter of the Earth; Saturn, Neptune, and Uranus are next in order of magnitude; the Earth and Venus are about the same size;

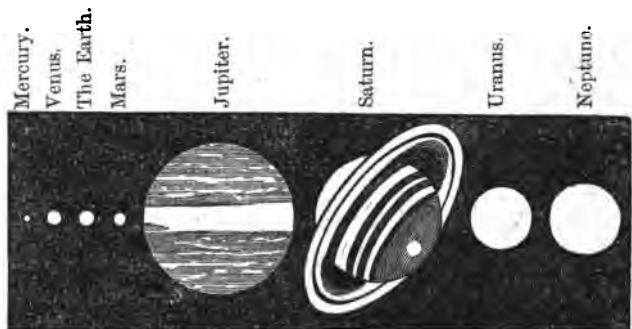


Fig. 22.

the diameter of Mars is only about one-half the diameter of the Earth; and Mercury is about one-third smaller than Mars. The Asteroids (which could not be shown in this diagram) are very small bodies, the largest of them not being more than 250 miles in diameter. The diameter of the sun is about 110 times the diameter of the earth, and his entire mass is vastly greater than that of all the planets put together. Constructed on the scale of the accompanying diagram, he would have been represented by a globe of about a foot in diameter.

TABULAR VIEW OF THE SOLAR SYSTEM.

Names.	Diameter in Miles.	Distance from the Sun in Miles.	Time of rotation on Axis.		Annual revolution round the Sun in Days.
			h.	m.	
Sun	882000	.....	607	48 ?	
Mercury	3140	37 mill.	24	5	87.969
Venus	7800	69 "	23	21	224.700
Earth	7926	95 "	24	0	365.256
Mars	4100	144 "	24	37	686.979
Asteroids {	Flora	209 "	.....	.....	1193.249
	Vesta	250 ?	.....	.....	1325.147
	Iris	226 "	.....	.....	1341.636
	Metis	227 "	.....	.....	1345.850
	Hebe	230 "	.....	.....	1379.994
	Astræa	244 "	.....	.....	1511.095
	Juno	79 ?	27	0 ?	1594.296
	Ceres	160 ?	.....	.....	1682.125
	Pallas .....	.....	.....	.....	1686.610
	Irene [*]
	Jupiter	87000	9	56	4332.584
	Saturn	79160	10	29	10759.219
	Uranus	34500	9	30 ?	30686.820
	Neptune	41500	.....	.....	60126.710

THE SUN.

51. This stupendous globe, nearly a million and a half times the bulk of our earth, is the great source of light and heat to all the planets, and by the attraction which he exerts retains them in their orbits. The telescope shows that there are dark spots upon his surface, and by observing them astronomers have ascertained that he revolves on his axis every 25 days, in the same direction as the planets move round him,—that is, from west to east.

MERCURY.

52. This little planet moves round the sun in about 88 days, at the distance of about 37,000,000 of miles, and revolves on his axis in 24 hours 5 minutes. The length of his day will, therefore, be rather more than ours, and the duration of his year about one-

* Discovered by Mr. Hind, May 19th, 1851. Many other asteroids have been since discovered.

fourth that of our year. The apparent motions, &c., of this planet are similar to those of Venus. (See Arts. 47 and 48.)

VENUS.

53. Of all the stars this is the brightest and most beautiful. Her distance from the sun is about three-fourths of the earth's distance, and hence she receives nearly double the light and heat from the sun.* She completes her revolution round the sun in about 225 days, and performs a rotation in 23 hours 21 minutes, on an axis inclined to the plane of her orbit at an angle of 15° . The length of her day is, therefore, nearly the same as ours, and the inclination of her axis shows that she has seasons similar to ours. She is surrounded by a high atmosphere; and from the irregularities observed on the edge of her crescent (see Art. 35), it has been inferred that she has enormous mountains upon her surface, probably much larger than any on our earth.

MARS.

54. This small planet is about $1\frac{1}{2}$ times the earth's distance from the sun. He takes about two of our years in revolving round the sun; and the length of his days is about the same as ours. The inclination of his axis to the plane of his orbit shows that he has seasons similar to those which take place on the earth. He is surrounded by an atmosphere; and the outline of continents and seas may be distinctly traced by means of a telescope. The red fiery color of his light is supposed to be produced by the ochery tinge of his soil, like that which red sandstone might produce. Bright white spots are seen about the poles, which are no doubt occasioned by the reflection of the sun's light from the polar snows and ice upon the planet; for it is observed that as each pole is turned toward the sun, the bright spots about it become less, owing to the melting of the snow by the sun's heat.

THE ASTEROIDS.

55. These bodies revolve round the sun, in orbits variously inclined to the ecliptic, between the orbits of Mars and Jupiter. They are so very small that their diameters have not yet been accurately determined. Some of them have very extensive atmospheres. They have all been discovered within the present century.

JUPITER.

56. This is the largest of the planets. He takes about twelve years to complete his revolution round the sun; and turns upon his axis in about ten hours. This rapid rotation has caused him to be much flattened at the poles.

* The light and heat derived from a luminous body varies inversely as the squares of the distance. Thus, taking the earth's distance from the sun as unity, we have heat of the earth : heat of Venus :: $(\frac{4}{3})^2 : 1^2 :: 9 : 16$.

The disk of Jupiter is always found to be crossed with dark parallel bands, or belts, with spots, as shown in *fig. 22*. Although these belts vary both in breadth and situation, yet they always run parallel to the equator of the planet. This appearance of the planet, no doubt, depends upon its atmosphere.

This magnificent planet has four moons, which constantly revolve about him from west to east, and accompany him in his path round the sun. Thus the satellites of Jupiter constitute a miniature system, to which their primary is the center, in all respects similar to the solar system, of which their central body itself is only a member.

Three of Jupiter's satellites are totally eclipsed at every revolution, by the great shadow which he casts from the sun. These eclipses are of great use in finding the longitude of places upon the earth.

Velocity of Light.

57. The eclipses of Jupiter's satellites have enabled astronomers to determine the velocity of light. When Jupiter is in opposition we are much nearer to him than when he is in conjunction. Owing to this difference of distance we see the eclipses of his satellites $16\frac{1}{2}$ minutes sooner in the one position than we do in the other.

Let *s* represent the sun (see *fig. 23*); *J* Jupiter; *M* the satellite eclipsed by the great conical shadow of the planet; *e* the position of the earth when Jupiter is in, or nearly in, opposition, and *e*

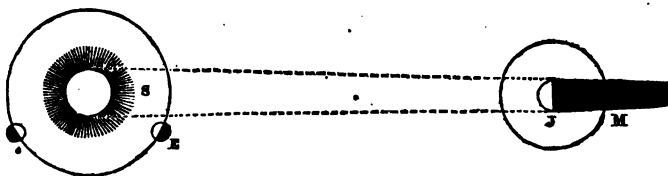


Fig. 23. Eclipse of Jupiter's satellites.

the position of the earth when he is in conjunction. Then the distance between *e* *e* is equal to, or nearly equal to, the diameter of the earth's orbit. Now the eclipse seen from *e* takes place $8\frac{1}{4}$ minutes before the calculated time, whereas when it is seen from *e* it takes place $8\frac{1}{4}$ minutes later than the calculated or true time; consequently the light takes $16\frac{1}{2}$ minutes to travel from *e* to *e*; that is, *light takes $16\frac{1}{2}$ minutes in traversing the diameter of the earth's orbit.*

SATURN.

58. Saturn's year is $29\frac{1}{2}$ times the length of our year, and the length of his day is about $10\frac{1}{2}$ hours. His distance from the sun is about $9\frac{1}{2}$ times that of the earth. The diameter at his equator is about one-tenth greater than the diameter at his poles. Like the earth, his axis is inclined to the plane of his orbit, and therefore he must have seasons. Saturn has eight satellites, seven of which had been known for sixty years before the eighth satellite was discovered. He is distinguished by having a thin broad ring surrounding his equator, as shown in *fig. 22*. This ring is concluded to be opaque, because it casts

a shadow on the surface of the planet; it is separated by different intervals, so that it is really a series of rings concentric with the planet: its whole breadth is 27,000 miles, and its thickness does not exceed 100 miles. The space between the inner side of the ring and the planet is 19,000 miles. The different parts of the ring revolve round Saturn in periods depending on their respective distances from him: the outermost ring revolves in about $10\frac{1}{2}$ hours. Saturn has dark belts like Jupiter, but rather broader and less strongly marked. The cause of these belts is no doubt atmospheric, as in the case of the belts of Jupiter..

URANUS.

59. This planet completes his revolution round the sun in rather more than eighty-four years. His mean distance from the sun is about nineteen times that of the earth. The discoverer of Uranus, Sir W. Herschel, believed that this planet had six moons; but only two have been observed by other astronomers. The motion of these satellites, round their primary, is from east to west, which is an exception to the law observed by the satellites of Jupiter, Saturn, and the Earth.

NEPTUNE.

60. Neptune, the most remote planet at present known in the solar system, completes his revolution round the sun in about 166 years, at about thirty times the distance of the earth from the sun. One satellite has already been observed, revolving round the planet at the distance of about twelve of its radii. This planet was discovered in 1846, and its existence was determined by calculations, based upon the law of gravitation, before it had been recognized as a planetary body by observation. This may be regarded as one of the greatest achievements of mathematical science.

COMETS.

61. Upward of 130 comets have been observed at different times, but only three have been identified as having been seen before. The comet which was seen in 1835, called Halley's comet, revolves round the sun in about seventy-six years. Their orbits are ellipses, or ovals, so very flat or eccentric, that the comets are invisible to us for the greater part of their revolutions round the sun.

Comets are not solid like the planets: they merely consist of a mass of vapor, the central portion of which is called the *nucleus* or head, being more dense than the rest. Sometimes this vapor extends to a great distance in the form of a *tail*, which is always in a direction contrary to the sun.

THE PLANETS MOVE IN ELLIPSES.

62. The true path of the planets round the sun are ellipses or ovals, differing, in general, but little from circles, of which the sun occupies what is called the focus.

Thus, in *fig. 24*, *E* represents the earth; *EDA* its elliptical orbit round the sun; *s* the sun in the focus of the ellipse.

Kepler discovered the elliptical motion of the planets, with other important facts, by observation, and Newton showed, by mathematical analysis, that this peculiar form of their orbits depends upon a certain law of the attractive force residing in the sun, called the law of gravitation.

When the earth is nearest the sun, as at *p*, it is said to be in its PERIHELION; and when the earth is furthest from the sun, as at *a*, it is said to be in its APHELION. The motion of the earth, in its orbit, is quickest when it is nearest the sun, or in its perihelion, and slowest when it is furthest from the sun, or in its aphelion. Hence it is that the time from the vernal to the autumnal equinoxes is about eight days longer than the time from the autumnal to the vernal equinoxes; thereby causing the summer in the northern hemisphere to be a little longer than the winter. The earth is about three millions of miles nearer to the sun in winter than it is in summer. If this be the case, it may be asked, why is our summer so much warmer than our winter? If we are nearer to the sun in winter than we are in summer, why should it not be warmer in winter in the place of colder? It is quite true that this would be the case were it not for other causes which far more than counterbalance the very small deficiency of temperature arising from this difference of distance from the sun. These causes have been briefly and incidentally explained in Art. 30, but it may be instructive to bring them here before the student in a distinct form.

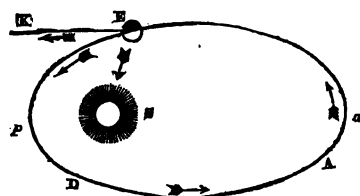


Fig. 24. Elliptical Orbit.

Heat of Summer.

(1.) The days in our summer months being very much longer than they are in our winter months, we must manifestly receive much more heat from the sun during the former period than we do during the latter.

(2.) In our summer the sun rises to a much greater height above the horizon than he does during our winter, and consequently he not only continues longer above the horizon, but his rays, coming more perpendicularly, strike in greater numbers upon any given portion of the earth's surface. Let *AB* represent a portion of the earth's surface, upon which the rays of the sun, *ABGE*, fall perpendicularly; and let *AC* be an equal portion of the earth's surface, upon which the rays of the sun, *ACFE*, fall obliquely,

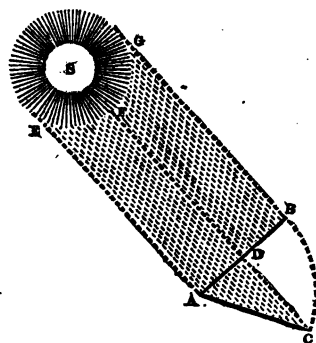


Fig. 25. Heat of summer.

or in a slanting direction. Now although the surfaces AB and AC are equal, yet it is plain that a much greater number of rays must fall on AB than upon AC . The rays of light and heat falling upon AB are included by the space $ABGE$, whereas those which fall on AC are included by the space $ADFE$; in fact, the heat which falls upon the small portion AD is spread out over AC .

GRAVITATION.

63. When a body moves in a curved line,—such as the path of the earth round the sun,—it must be under the action of two forces; one an impulsive force, or force of projection, the other a constantly acting force, such as the attraction of gravitation. We have a familiar instance of this when a stone is projected obliquely upward from the top of a high tower: the stone moves in a curve, called a parabola, in consequence of the motion of projection and the attraction of the earth. Now as we increase the force of projection, the stone will be longer before it reaches the earth's surface; indeed, it is not difficult to conceive the force of projection to become so great that the stone shall not return to the earth's surface at all, but shall move round the earth like a little satellite similar to the moon.

The earth, and all the other planets, had at first a motion of projection given to them; and this motion would have carried them away into infinite space, had it not been for the sun's attraction. If the attractive force of the sun were to cease, the earth at E (see *fig. 24*) would fly off from its orbit in the tangent line EK ; and on the contrary, if the motion of projection were stopped, the earth would be drawn in toward the sun; but the two forces of projection and gravitation are so nicely adjusted, that the earth continually moves round its great center of attraction, in an elliptical orbit, constantly returning at every revolution (at least virtually) to the point from which it started. This law of gravitation,* which holds true with respect to the sun and the planets, also holds true with respect to the motion of the satellites round their respective primaries.

ATMOSPHERIC REFRACTION.

64. The atmosphere, which surrounds the earth, is of variable density, that is, the higher we ascend the rarer it becomes. It may therefore be considered as consisting of a series of strata or layers, $KGIM$, $GDFI$, $DACF$, &c. (see *fig. 26*), of decreasing density. Now air, as well as all transparent substances, possesses the power of REFRACTING the

* According to the law of gravitation;—(1.) All bodies attract one another with forces proportional to the masses of matter which they contain;—(2.) The force of attraction decreases as the squares of the distances increase.

rays of light, or bending them out of their straight course; thus the rays of light, proceeding from a star, or any heavenly body, become bent more and more downward as they pass through the atmosphere, and the star is seen, not in the direction which it actually lies, but in the direction which these rays have at the instant of arriving at the eye of an observer; the effect of this is, to cause the star to appear higher in the heavens than it really is. In *fig. 26* let s represent a star beyond the limits of the atmosphere $KACM$; SBm the straight course of a ray of light proceeding from the star. In passing through the layer of atmosphere $ACFD$, the ray SB is bent down into the direction BE ; now if the next layer $DFIG$ were of the same density as $ACFD$, the ray BE would proceed in the straight line BEH , but as the former is denser than the latter, the ray is bent down into the direction EH ; and so on through every successive layer, until the ray comes to the eye of the observer.

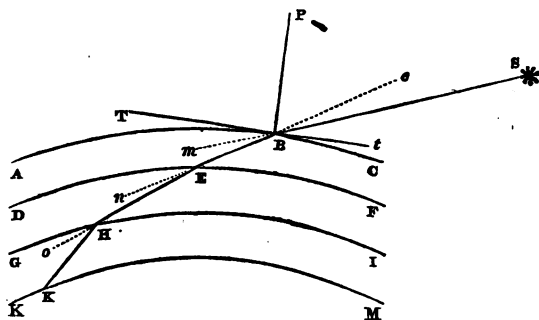


Fig. 26. Refraction.

As the ray of light proceeds downward, the strata of air become more and more dense, which causes the ray to become more and more bent in its passage; hence it is that the course of the refracted ray through the atmosphere is that of a curve which becomes more and more concave as it approaches the earth, as shown in *fig. 27*; where m is the luminous object; ma the straight direction of the rays of light, which, meeting the atmosphere at a , are by refraction bent into the curve aA ; Am is the direction which the refracted ray has when it arrives at the eye of the observer at A ; and Am is the direction in which the star will be seen: thus the refraction of the atmosphere causes us to see the heavenly bodies apparently higher above the horizon than they are in reality. The body m may actually be beneath the horizon, and yet be visible to a person at A . The atmospheric refraction elevates the apparent position of the heavenly bodies most when they are near the horizon; and at the zenith it does not affect their position at all.

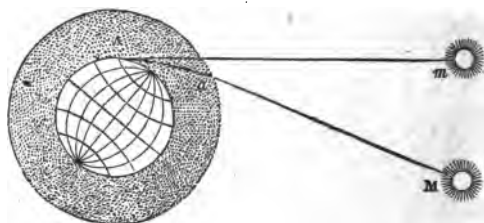


Fig. 27. Atmospheric Refraction.

OVAL FORM OF THE SUN AND MOON NEAR THE HORIZON.

65. This remarkable appearance is occasioned by atmospheric refraction. The upper half of the sun or moon's disk, as the case may be, being less raised by refraction than

the lower half, causes the vertical diameter of the disk to be lessened, while the horizontal diameter remains unchanged; hence the disk appears of an oval shape.

TWILIGHT.

66. Twilight is that light which we enjoy for about an hour and a half before the sun has appeared above the horizon, and for about the same time after he has set. This beautiful effect is caused by the REFLECTION of the sun's light from the higher regions of the atmosphere. Some time before we have any direct transmission of light from the sun, his beams illuminate the higher portions of the atmosphere, and then this illuminated portion transmits light to us. In *fig. 28* let *GAE* represent the earth; *GK CDE* a portion of its atmosphere; *A* the place of an observer; *AR* his horizon; and *s* the sun considerably below the horizon, and of course invisible to a person at *A*. Now that portion of the atmosphere represented by *CBED* will be illuminated by the sun, while *AOKG* will be in comparative darkness; and the illuminated portion *CB D* will be visible to a person at *A*, and the light proceeding from it will occasion his twilight. The duration of twilight varies with the latitude and the season of the year. At the equator the duration of twilight is always short, whereas at the poles it lasts for upward of four months. Twilight begins and ends when the sun is about eighteen degrees below the horizon.

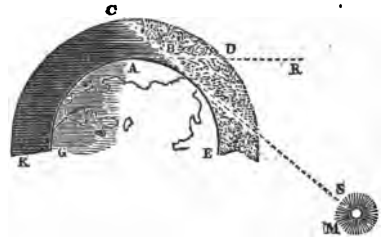


Fig. 28. Cause of Twilight.

THE TIDES.

67. The alternate flowing and ebbing of the sea is called the tides. They are produced by the attraction of the sun and the moon upon the waters of the ocean; but chiefly by the attraction of the moon; for as she is much nearer to the earth than the sun, her attractive force upon the waters is considerably greater than that of the sun.

For a little more than six hours, the sea, in certain places, gradually swells and then flows into harbors and the mouths of rivers; this is called FLOOD TIDE. At the end of this time the ocean has attained its greatest height; this is called HIGH-WATER. The waters then begin to EBB or fall, which they continue to do, for a little more than six hours, until they arrive at their lowest level; this is called LOW-WATER. Thus the waters of the ocean, day after day, alternately swell and fall in a little more than six hours; so

that high-water takes place twice in every 24 hours 50 minutes, this being the time which the moon takes in passing from the meridian of a place to returning to the same meridian again. If the moon were stationary, the interval between high-water of one day, and high-water the next, would be exactly 24 hours; for the moon would return to the meridian of the place in this time; but while the earth is performing a revolution on its axis, the moon advances about 13° in her orbit, so that it takes the earth about 50 minutes more to bring the same place opposite to, or on the same meridian with, the moon.

68. In explaining the cause of the tides, we shall first speak of the moon's attraction alone. If the earth were an exact sphere covered with water, and if there were no external attraction exerted upon it, the water would arrange itself uniformly over the surface, forming a coating like the rind of an orange; but when the earth is brought under the influence of an attractive body, like the moon, this uniformity in the distribution of the water no longer subsists. In *fig. 29* let *E* represent the earth surrounded by water; *M* the moon; and *S* the sun; then

since the moon's attraction is greatest upon the objects which lie nearest to her, the water at *a*, directly below the moon, will be more attracted by her than the water which lies further off; hence it is plain that the water at *a*, beneath the moon, must be drawn up, or, as it were, heaped up; now as the earth revolves on its axis, successive parts of its surface

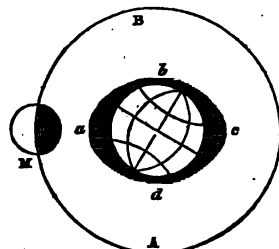
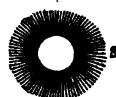


Fig. 29. Spring Tide, at New Moon.

must pass under the moon, and these parts will have high-water in regular succession. But for a similar reason there will also be high-water at *c* on the opposite side of the earth; for the water at *c* must be less drawn toward the moon than the water at *b* or *d*, or any parts between *c* and *b*, or *c* and *d*, hence it follows that the water must be heaped up toward *c*. At *b* and *d* there will be low-water.

It will now be readily seen why we have twice high-water, and twice low-water, in the course of every 24 hours 50 minutes.*

69. We have hitherto regarded the attraction of the moon alone as the cause of the tides; but this is not strictly true, for the sun's attraction very much affects the magnitude of the tides.

The largest tide takes place when the moon is at her change, or at her full moon;

* It must be observed that the tide is not at its highest when directly under the moon, but about 2 hours later; for since the full effect of the moon's attraction on the waters is not instantaneous, high-water will not take place until the moon has passed the meridian: in the same way, the hottest part of the day does not take place till some time after noon; and also the month of July is always hotter than the month of June.

moon; for in both these cases the attractive forces of the sun and moon combine in raising the waters. These are called **SPRING TIDES**. On the contrary, the lowest tides take place when the moon is at the beginning of her second and fourth quarters,—that is to say, when she is half moon; for then the attractive forces of the sun and moon act so as to diminish each other's effect. These are called **NEAP TIDES**.

Fig. 29 represents *the spring tide at new moon*. Here the attractive forces of the sun and moon obviously co-operate in raising the waters of the ocean at *a* and *c*.

Fig. 30 represents *the spring tide at full moon*; where *s* represents the sun; *m* the moon at her full; and *e* the earth. Here the attractive forces of both the sun and the moon tend to draw the waters away from *b* and *d*, and to accumulate them, or heap them up, at *a* and *c*.

Fig. 31 represents *the neap tides at half moon*; where *m* represents the moon, either at the beginning of her second, or at the beginning of her fourth quarter. Here the attraction of the sun tends to diminish the flow of the waters at *b* and *d*, and hence the tides at these periods are smaller than at any other.

Thus in the course of a lunar month we have two spring tides and two neap tides.

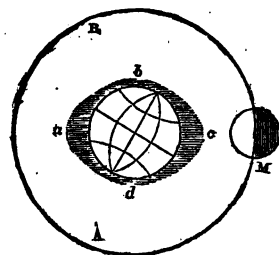
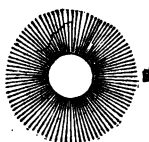


Fig. 30. Spring tide at full moon.

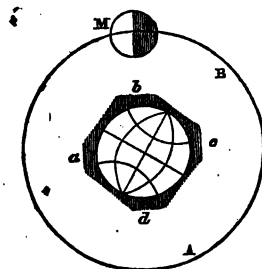
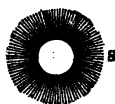


Fig. 31. Neap tides.

THE FIXED STARS.

NUMBER OF THE FIXED STARS.

70. The number of the fixed stars exceeds all computation. Viewed through a powerful telescope, *the Milky Way*, or *galaxy*, appears like great groups of constellations. Dr. Herschel counted 600 stars within the view of his telescope at one time, and in one portion of the Milky Way he computed that the number of stars exceeded a quarter of a million. But if the power of our telescopes were still further increased, there would be no limit to the number of stars which we might observe.

DISTANCE OF THE FIXED STARS.

71. It has been ascertained that the nearest of the fixed stars are at such enormous distances from us, that it would take their light, traveling at the rate of about twelve millions of miles in a minute, three years and a quarter to reach us. The truth of this may be illustrated in the following manner:

Look at two trees at no great distance from you, and observe the apparent distance between them; now change your position by walking either to the left or to the right, and observe that the apparent distance between the trees is decidedly changed; indeed, you may come to a position where the two trees would appear as one, or, more correctly speaking, in the same straight line. Here, then, we conclude that when objects are near to us, their apparent distances from one another are very much affected by our change of position. Again, proceeding in the same manner, look at two objects more remote from you; then you will find that your change of position scarcely at all alters the apparent distances of the objects. Here, then, we conclude that when objects are very distant from us, their apparent distances from one another are very little affected by our change of position. Now the earth, as it revolves round the sun, undergoes a change of position measured by the diameter of its orbit, or 192 millions of miles. The earth, therefore, is 192 millions of miles nearer to certain fixed stars at one time than another; yet, notwithstanding this enormous change of position, there is scarcely any difference observed in the apparent distances of the stars from one another. How immensely great, then, must their distances be from us!*

THE STARS HAVE MOTION.

72. The stars have a motion through space. Thus, for example, a small star in the constellation of the Swan has been found to move annually over five seconds of the arc of the heavens. Now, according to Arago, the distance of this star from us is not less than 400,000 times the distance of the earth from the sun. In order, therefore, that this star should move over five seconds annually, it must actually travel many millions of miles in this time. Hence it is only in a relative sense that we can speak of the stars as being fixed; absolutely considered, there is probably nothing fixed in the universe.

* Astronomical instruments have been made with such nicety that a difference may be detected in the apparent distances of two objects when their distance from us is 100,000 times the distance between the two points of observation. But as only a very minute difference can be detected by our best instruments in the apparent distances of the stars when viewed from the opposite points of the earth's orbit, it follows that the nearest stars must be at least 100,000 times 192 millions of miles from us. Mr. Henderson discovered that the star called Centauri is altered in its apparent position by only about one second. Assuming this to be the case, the distance of this star from us must be about half a million of times the earth's distance from the sun. This angular change in position is called the parallax of the star. Not more than ten stars have at present been found to have any parallax; and that of the star Centauri is the greatest which has yet been observed.

MULTIPLE STARS.—GRAVITATION EXTENDS TO THE STARS.

73. Certain stars, although they appear single to the naked eye, are found to be double or treble stars when viewed through a good telescope. Stars of this kind are very numerous. In 120,000 stars examined by M. Struve, one in every forty was found to be a multiple star,—that is, a group of two, three, or even four stars; indeed, it seems possible that, were our telescopes sufficiently powerful, we should find all the stars which appear single to the naked eye to be really groups of stars.

74. In these multiple stars one is always observed to be much more brilliant than the rest. This brilliant star in each group is the central sun, round which the others revolve, in the same manner as the planets in our system revolve round the sun. These multiple stars, therefore, are systems of worlds similar to our solar system, thereby proving that the law of gravitation, which animates and controls the planetary bodies, exists throughout the remote regions of the celestial spaces. How beautiful it is thus to mark the unity of plan manifested in the constitution of the universe! The law of attraction which causes a stone to fall to the ground, which gives the globular form to the mass of the earth, and which guides the planets in their motion round the sun;—that same law binds the stars to one another in each group of multiple stars; and it may not be improbable that all these worlds, and systems of worlds, which people the immensity of space, are but parts of one grand integral system, which, under the great controlling principle of gravitation, are linked to one another, as well as to one vast central mass, fixed in the unfathomed depths of the universe.

“ That very law which molds a tear,
And bids it trickle from its source,—
That law preserves the earth a sphere,
And guides the planets in their course.”

THE DIVISIONS OF TIME.—THE CALENDAR.

75. The motions of the sun and moon have been taken in all ages as the measure of time. The diurnal motion of the sun is the measure of our day; his revolution in the ecliptic gives the length of our year; and the periodic return of new moon is the basis of our division of time into months.

ASTRONOMICAL AND SIDEREAL DAY.

76. The ASTRONOMICAL DAY is 24 hours long; it is the mean of the intervals between the noon of one day and the noon of the succeeding one.

The period which the earth takes to revolve on its axis is constantly the same, viz. :

23 hours, 56 minutes, 4 seconds. This is called a **SIDEREAL DAY**, for it is the time which any meridian on the earth takes in revolving from a fixed star to that star again.

The astronomical day is nearly 4 minutes longer than the sidereal day. This is caused by the sun's motion in the ecliptic: for while the earth is turning on its axis, the sun is advancing among the stars, and hence it requires the earth to make rather more than a complete revolution to bring the same meridian under him.

EQUATION OF TIME.

77. Owing to certain causes,* which need not at present be explained, the sun does not move uniformly among the stars, and hence we find that the interval between two successive noons is not always the same. A clock, therefore, which keeps true time will not always correspond with the time as indicated by the sun. Thus, for example, if it be 12 o'clock to-day by a watch keeping true time, when the sun is exactly at noon, or on the meridian, then it will not be exactly 12 o'clock by the watch to-morrow when the sun is on the meridian: the time by the watch may be a little before or after 12 o'clock, according to the season of the year. This difference of time between the clock and the sun is called **THE EQUATION OF TIME**. Almanacs contain the amount of this difference for every day of the year, so that we can always tell how much before or after 12 o'clock the sun will be on the meridian on any proposed day.

SOLAR YEAR.—JULIAN CALENDAR.

78. As the return of the sun to the same meridian marks the length of the day, so the return of the sun to the same equinox gives the length of the year.

The solar year contains 365 days, 5 hours, 48 minutes, 49.7 seconds; or 365 days, 6 hours, nearly. But as the common or civil year consists of only 365 days, the solar year is about a quarter of a day longer than the civil year, and therefore if this year always contained 365 days, there would be an error of a day committed in the course of every four years. Now, in order to correct this error, Julius Cæsar, the great Roman general, enacted that every fourth year should consist of 366 days. This year is called **leap-year**, and the additional day is added to the month of February, which therefore consists of 29 days in leap-year. This mode of reckoning is called the **JULIAN CALENDAR**.

GREGORIAN CALENDAR.

79. Now if the solar year had consisted of 365 days, 6 hours, exactly, no further correction would have been necessary; but this is about 11 minutes too much, and con-

* The irregularity of the sun's apparent motion arises from the following causes: First, upon the inclination of the ecliptic, or sun's apparent path, to the plane of the equator; and, secondly, upon the elliptic form of the earth's orbit, which occasions the earth to move quicker when in the perihelion, or nearest the sun, and slower when in the aphelion, or furthest from the sun.

sequently the Julian Calendar introduced an error of 44 minutes every 4 years, or about a whole day in 130 years. This error in the course of centuries became considerable. Thus, in the year 1577, the vernal equinox happened on the 11th of March in the place of the 21st. Pope Gregory, in the year 1582, corrected the calendar in the following manner: the 5th of October was called the 15th, to correct the error which had been committed since the time of Julius Cæsar; and to prevent the error happening again, it was agreed that every fourth year should be leap-year, as in the Julian Calendar, excepting that every hundredth year, for three successive centuries, should be common years, and the fourth hundredth should be a leap-year. Thus, 1700, 1800, and 1900 are common years, and 2000 is a leap-year. By this mode of reckoning, the error in 4000 years will not exceed one day. This is called the GREGORIAN CALENDAR.

The Julian Calendar is called THE OLD STYLE, and that of the Gregorian THE NEW STYLE.

The Gregorian Calendar was at once received by all Roman Catholic countries; but it was not adopted in this country until the year 1752.

EXERCISES.

THE questions given throughout this book are not merely intended to give an analysis of the matter going before, but also, by a suggestive course of reasoning, to lead the pupil to reflect and reason upon, and even in some cases to extend, the knowledge which has been communicated to him.

THE STARS.

Teacher. What is the point directly over our heads called?

Pupil. The zenith.

T. What do you mean by the horizon?

P. That line all round us where the sky and the earth appear to meet.

T. What shape does the horizon appear to have?

P. It has a circular shape, and bounds our view on all sides.

T. What point in the heavens is that which lies directly below our feet?

P. It is called the nadir.

T. What would our zenith be to a person living on the opposite side of the earth?

P. It would be his nadir.

T. If I cut a globe (say an orange) into two equal parts, what is each part called?

P. Each part is called a hemisphere, or half-sphere.

T. What do the heavens appear like?

P. A vast dome, or concave hemisphere.

T. Why do we not see the stars during the day?

P. Because of the superior light of the sun.

The teacher should continue to give questions of this kind, taking care to vary their form, until the pupil is thoroughly master of the subject.

CARDINAL POINTS.

Teacher. In what part of the heavens does the sun rise?

Pupil. He rises in the east and sets in the west.

T. At noon the sun shines exactly upon the front of my house; now tell me the direction of the front wall of my house.

P. It must lie in a line extending from east to west.

T. What would be the direction of each gable in this case?

P. Each gable wall would lie in a line extending from south to north.

T. If the line *ns* lies north and south, and *ew* lies east and west, how do these lines lie with respect to each other?

P. They lie at right angles to each other,—that is, *we* is at right angles to *ns*; or, in other words, *we* is perpendicular to *ns*.

T. Describe the cardinal points in a map.

P. The top is north, the bottom south, the right hand east, and the left hand west.

T. What will be the direction of your shadow when you go home to-night, supposing the sun to be shining?

P. It will be cast toward the east.

And so on.

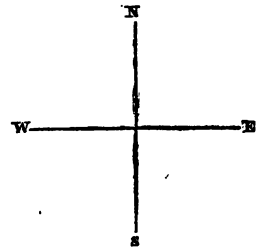


Fig. 32. The Cardinal Points.

DIURNAL MOTION OF THE HEAVENS.—MAGNITUDE OF THE STARS.

Teacher. What is meant by the diurnal motion of the heavens?

Pupil. The daily revolution of the heavens about the polar-star.

T. In what direction does this apparent motion take place?

P. From east to west. (Why?) Because the stars appear to rise in the east and set in the west.

T. What do you mean by a body having an *apparent* motion?

P. When a body appears to us as if it moved, without really doing so, we may say that its motion is only apparent.

T. How many stars may be seen with the naked eye?

P. About two thousand.

T. What stars are said to be of the first magnitude?

P. The largest and brightest.

T. What stars belong to the sixth magnitude?

P. Those which are just visible to the naked eye.

And so on.

FIXED STARS AND PLANETS.—CONSTELLATIONS.—SIGNS OF THE ZODIAC.

Teacher. What are fixed stars?

Pupil. Those stars which do not change their distances from one another.

T. What are those stars called which do not always remain in the same place?

P. They are called planets.

T. Which stars twinkle most?

P. The fixed stars.

T. What do the planets look like, when viewed through a good telescope?

P. They look like little luminous balls.

T. What is a constellation?

P. A constellation is a group of stars.

T. What is meant by the two Pointers in Charles's Wain?

P. Those two stars in the back of the supposed wagon which nearly point toward the polar-star.

T. What is a celestial globe?

P. A celestial globe represents the appearance of the heavens, with the different stars and constellations marked upon it.

T. What is the upper star in the Pointers called?

P. It is called Dubhe.

T. Through what portion of the heavens do the planets appear to move?

P. Through a belt or band of stars, containing 12 constellations, called the Signs of the Zodiac.

T. What is the ecliptic in the heavens?

P. It is the apparent annual path of the sun. It is marked out by the constellations of the zodiac.

T. Why was the term zodiac given to these constellations? Can you name the signs of the zodiac?

GENERAL PRINCIPLES OF ASTRONOMY.

Teacher. Objects appear to us to get less and less as they are removed from us. Give some familiar illustration of this. Describe the appearance of a balloon as it ascends.

Pupil. As the balloon rises in the air, it appears to us to get smaller and smaller, until at length it gets so far away from us as to appear very little larger than a foot-ball.

T. In order, therefore, to know the real size of a body, we must not only observe its apparent size, but we must also know its distance from us. Now let there be two trees of the same height, and suppose one of them to be at double the distance of the other, what would be their apparent magnitude?

P. The more distant tree would appear only about half the size of the other.

T. What is the moon?

P. A great globe, smaller than the earth.

T. Why does she appear so small to us?

P. Because she is many thousands of miles from us.

T. If a balloon were 10 miles from us, how would it appear?

P. I should say that we could not see it at all. (Or in other words :) It would be invisible.

T. When a body appears to move, this appearance may be produced in two ways : what are they ?

P. First, the apparent motion may be produced by the body actually moving in the direction in which we think it moves ; and, secondly, it may be produced by our having a motion in a direction contrary to that in which the body appears to move.

T. What have you to say relative to the appearance of objects when you are moving in a railway carriage ? The heavens appear to turn round in every 24 hours : how may this be explained ? What is the shape of the earth ? In what time does it turn upon its axis ? What does this motion of the earth give rise to ?*

T. Give me a familiar instance of a body turning or spinning round on an axis.

P. A spinning-top.

T. Where is the axis in this case ?

P. It is the line round which it appears to spin.

T. The earth moves round the sun in the course of a year : how does this affect the appearance of the sun ?

P. It gives rise to the *apparent* motion of the sun in the ecliptic.

T. What are the planets ? What do they revolve round ? What is the sun to them ? Whence do they derive their light and heat ? What is the path of a planet round the sun called ?

SOLAR SYSTEM.

Teacher. Give a familiar example of one body revolving round another.

Pupil. A horse revolving round a man in the center of a ring.

T. Of what does the solar system consist ? In what direction do the leading planets revolve round the sun ? In what plane do the orbits of the planets nearly lie ? In what direction do they turn round on their axes ? Name the planets in the order of their distances from the sun. What is a satellite ? How many primary planets are there at present known in the solar system ? How many satellites are there ? Mention the number of satellites which respectively revolve round the different planets, &c.

T. If I move this orange round a candle, what would this rudely represent ?

P. We may consider the candle as the sun, and the orange as a planet moving round him in its orbit.

T. Now while I keep the orange moving round the candle, suppose I move this nut round the orange in such a manner that the nut shall make about 12 revolutions round the orange, while the orange makes one revolution round the candle : what would this rudely represent ?

P. It would represent the motion of the earth round the sun, and at the same time the motion of the moon round the earth.

* The pupil is supposed to answer these questions in succession.

T. What are comets? Who first taught correct views relative to the solar system? Who was Pythagoras? Who revived the system first taught by Pythagoras?

THE EARTH AND ITS MOTION.—FORM AND SIZE OF THE EARTH.

Teacher. Who first sailed round the world?

Pupil. MAGELLAN.

T. Who first made the attempt?

P. COLUMBUS.

T. If the earth were an unbounded flat surface, what would be the consequence of a vessel constantly sailing from any place?

P. The further the vessel sailed, the further she would get away from the place.

T. But ships never sail in a direct line from any place; how then can they be said to sail constantly in the same direction?

P. Ships may sometimes go to the right, or to the left, of their direct course, yet still they pursue a certain general direction.

T. Just in the same way, you might say that a little fly may move round *this globe*,* though the creature may go in a zigzag course. Why do we not see the hull, when a ship has sailed some distance from us?

P. Because the round part of the earth's surface comes between us and the hull.

T. After the hull of a ship has disappeared, what should you do to get a sight of it again?

P. I should get to the top of some high tower or hill.

T. What is the shape of the earth?

P. It is the shape of a ball or globe.

T. Some boy, I think, just said that the earth is round. Now, the upper part of my hat is *round*: is the earth then the shape of my hat?

P. Surely not; the earth is *round in every direction*, but your hat is round only in one direction.

T. What shape does my hat now *appear* to have?

P. A sort of oblong shape.

T. How do you know that the earth is round in every direction?

P. Because, wherever we may be, we always find that the horizon has a round shape; which shows that the earth must be everywhere round to present this appearance.

T. What do you think that seamen do, when they want to observe a distant sail?

P. They climb to the topmast.

* In giving these lessons, the teacher must be provided with a small white globe, having a rod passing through it to represent the axis of the earth, and having also all the essential lines upon the terrestrial globe, painted in strong black lines.

T. Why?

P. That they may see a greater way over the ocean.

T. (Moving his finger round the globe.) What has my finger moved over?

P. The circumference of that globe.

T. What is a line passing through the center of the earth called?

P. The diameter.

T. If the line only went to the center, what would it then be called?

P. The radius.

T. What part of the diameter is the radius?

P. One-half.

T. Now in this globe every point on the surface is at the same distance from the center. What have you then to say respecting the radii of a globe?

P. That they are all equal to each other.

T. How many times is the circumference of a globe greater than the diameter?

P. A little more than three times.*

T. If the length of a line stretching from London to York be 200 miles, how many times must this line be repeated to go round the earth?

P. About 125 times; because 25,000 divided by 200 gives 125.

T. How long will it take a man to walk round the earth, supposing that he travels 25 miles every day?

P. About 1,000 days, or nearly three years; because, number of miles traveled per day = 25 miles;

$$\therefore \text{Number of days to travel round the earth} = \frac{25,000}{25} = 1000.$$

DIURNAL MOTION OF THE EARTH.—LINES UPON THE GLOBE.

Teacher. How much of the earth's surface does the sun enlighten at one time?

Pupil. One-half.

T. By what means is every part of the earth's surface brought within the light and heat of the sun?

P. The earth is made to turn round upon its axis in the course of every day.

T. (Turning a globe round.) Now where is the axis in this revolving globe? Is there a real axis or only an imaginary one?

P. The axis is only imaginary, and it is the line about which the globe appears to turn.

T. What have you now to say respecting the axis of the earth?

P. That it is the line about which the earth appears to turn.

* The ratio commonly given is 8.1416.

T. What are the poles upon the earth?

P. The two points where this imaginary axis meets the earth's surface.

T. On what point is my finger now placed?

P. On the north pole.

T. (Tracing the equator with his pointer.) What is this line called, and how is it placed with respect to the poles?

P. It is called the equator, and lies at the same distance from either of the poles.

T. How does the equator divide the globe?

P. Into two equal parts. One is called the northern hemisphere, and the other the southern hemisphere.

T. Upon what hemisphere is my hand now placed?

P. The northern hemisphere.

T. Is there any other way in which the changes of day and night might be produced?

P. Yes; the sun might turn round the earth in the course of a day.

T. If a poor woman wanted to roast a joint of mutton before the fire, what would she do in order to have every part equally roasted?

P. She would tie a piece of string to the mutton, and make it turn round before the fire.

T. Is there any other way in which this might be done? Now think.

P. The fire might be made to turn round the meat.

T. But which of these methods is the better?

P. The first method, certainly; because it must be far less trouble to make the meat turn round before the fire than to make a machine for turning the fire round the meat.

T. What should you say if a man proposed to do this?

P. That although he might show some ingenuity, yet he would be a very foolish person.

T. Now it is equally ridiculous to suppose that the sun turns round the earth. It is too monstrous for us to conceive it possible that Almighty God, who is the fountain of all wisdom and goodness, could effect any of his purposes by the agency of means which it would appear unsuitable, even on the part of his creatures, to employ.

LATITUDE AND LONGITUDE.

Teacher. (Moving his pointer round the globe.) How many degrees have I moved my pointer over?

Pupil. 360°.

T. (Moving his pointer from the pole to the equator.) How many degrees have I now moved my pointer over?

P. 90° , or a quadrant.

T. Why?

P. Because it is a quarter of the whole circumference, and the quarter of 360° will be 90° .

T. Now, knowing the circumference of the earth to be 25,000 miles, I want you to tell me the length of 1° .

P. About $69\frac{1}{2}$ miles; because the length of the whole circumference, or 360° , being 25,000 miles, the length of 1° will be the 360th part of 25,000 miles, or $69\frac{1}{2}$ miles, nearly.

T. (Moving his pointer over a meridian.) What is this line called?

P. It is a meridian.

T. (Moving his pointer on the equator, between the first meridian and the meridian passing through a place.) What is this distance called?

P. The longitude of the place through which the meridian passes.

T. (Putting his pointer on a place in North America.) What kind of longitude will this place have?

P. West longitude.

T. (Moving his pointer on a parallel of latitude.) What is this line called?

P. A parallel of latitude.

T. Why is it called a *parallel* of latitude?

P. Because it is drawn parallel to, or even with, the equator.

T. (Putting his pointer on a place in the southern hemisphere.) What kind of latitude will this place have?

P. South latitude.

T. Here is a meridian passing through a place. Now if this distance (tracing with his pointer the distance between the place and the equator) be 35° , what is the latitude of the place?

P. 35° .

T. Upon what line then is the latitude of a place measured?

P. Upon a meridian line passing through the place.

T. How many things must be given to fix the position of a place upon the earth?

P. Two things; the longitude and latitude.

T. Is this parallel of latitude a great or small circle?

PROBLEMS ON LONGITUDE.

Teacher. When it is noon at Greenwich, what time will it be to a place having 45° west longitude? *Ans.* Nine o'clock in the morning.

T. When it is noon at Greenwich, what time will it be to a place having 60° east longitude? *Ans.* Four o'clock in the afternoon.

T. When it is noon with us, what time will it be to all places on our opposite meridian? *Ans.* It will be midnight.

T. In what time will the earth turn round 1° ? *Ans.* In 4 minutes.

Because, time in moving round $360^\circ = 24$ hours.

$$1^\circ = \frac{24 \times 60}{360} \text{ min.} = 4 \text{ min.}$$

T. When it is noon at Greenwich, what time will it be to a place having 40° east longitude?

It has been shown in the last question, that places having a difference of 1° of longitude, will have a difference of four minutes in time; therefore, a difference of 40° in longitude, will have a difference of time equal to forty times four minutes, or two hours and forty minutes. But as the place has east longitude, it will have its noon before us, and consequently, when it is noon with us, it will be two hours forty minutes past noon at the place.

T. The captain of a ship finds that the pointer of his clock, keeping Greenwich time, is at 4 o'clock in the afternoon when the sun is in the meridian of the place of observation; what is the longitude of the ship? *Ans.* 60° west longitude.

T. If the pointer of the clock, in the last example, be at seven o'clock before noon, what will then be the longitude? *Ans.* 75° east longitude.

THE TROPICS AND ECLIPTIC.—THE ZONES.

Teacher. (Moving his pointer on the tropic of Cancer.) What line is this called?

Pupil. The tropic of Cancer.

T. When does the sun shine perpendicularly over this line?

P. On our midsummer day, or the 21st of June.

T. (Moving his pointer on the arctic circle.) What line is this called?

P. The arctic circle.

T. What places this line upon the globe?

P. The fact, that on our midsummer day the sun's light extends $23\frac{1}{2}^\circ$ over the north pole.

T. (Moving his pointer on the tropic of Capricorn.) What line is this called? And why is it placed here?

P. The tropic of Capricorn. The sun shines perpendicularly over it on our midwinter day, or the 21st of December.

T. (Tracing out the torrid zone.) What zone is this?

P. The torrid zone.

T. By what lines is it bounded?

P. It is bounded by the tropics of Cancer and Capricorn.

T. (Tracing out the north temperate zone.) What zone is this, and how is it bounded?

P. It is the temperate zone, and it is bounded by the tropic of Cancer and the arctic circle.

T. How many zones are there, and what are they called?

P. There are five zones; the torrid, the two temperate, and the two frigid zones.

ANNUAL MOTION OF THE EARTH.—CAUSE OF THE SEASONS.

Teacher. (Moving the globe round the candle, &c.) How many motions has this globe?

Pupil. It has two motions; one on its axis, and the other round the candle, which we suppose to represent the sun.

T. What are these two motions of the earth called?

P. The one is called the diurnal motion, and the other the annual motion.

T. Where is the *orbit* of this globe?

P. That line or path in which it is moving round the candle.

T. (Bringing the globe to the position *c*. See *fig. 14*.) Now, when the earth is in this position, what season have we?

P. Summer, because the sun shines more over the northern than over the southern hemisphere.

T. (Holding a pointer from the candle to the tropic of Cancer *c*.) To what point on the earth's surface would the sun be now shining perpendicularly?

P. To a point in the tropic of Cancer.

T. How much on every side of this point will the sun's light extend?

P. It will extend 90° over the earth on every side, because the sun enlightens one-half the earth at one time.

T. How far over the north pole will his light, therefore, at this time extend?

P. As much over the north pole as the tropic of Cancer is from the equator; that is, $23\frac{1}{2}^\circ$.

And so on to the positions *d*, *t*, and *b*.

Teacher. (Moving a rod without changing its direction.) What have you to say with regard to the position of this rod?

Pupil. That although it is being moved in a circle, yet it still maintains its *parallelism*.

T. Just in the same way, you might say, as the earth preserves the parallelism of its axis, while it revolves round the sun. What do you mean by the parallelism of the earth's axis?

P. That it is always parallel to itself, or that it constantly lies in the same direction.

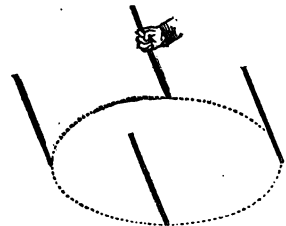


Fig. 83. Parallelism.

T. (Moving the globe round the candle, with the axis vertical.) Why does this position of the axis not account for the seasons?

P. Because the sun would always shine perpendicularly over the equator, and therefore both hemispheres would always enjoy the same amount of light and heat.

T. What things are necessary in order to account for the seasons?

The remainder of the work may be dissected in the same manner.

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They show the New Cities and Towns in the New States and Territories.

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We have added to our list the past season:—

1st. A 30 inch Terrestrial Globe, the largest ever made in this country. Handsomely mounted on a solid Mahogany frame, with compass. An acquisition to any School, Academy, or College.

2d. Copley's 16 inch Globes, Terrestrial and Celestial. These have been out of market for two years. They have, besides the latest changes and divisions, the Isothermal Lines of Temperature, and the deep Sea Soundings. They are, without exception, the most full and complete of any in market.

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10 " 2.11 "

6 " .78 "

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* 10 " " " Bronze Stand, per pair,	24 00
* 10 " " " Wood Stand, per pair,	22 00
* 6 " " " Bronze Stand, per pair,	9 00
* 6 " " " Bronze Semi-Frame, per pair,	6 50
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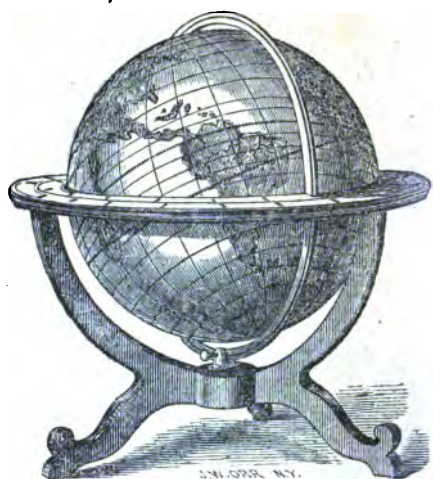


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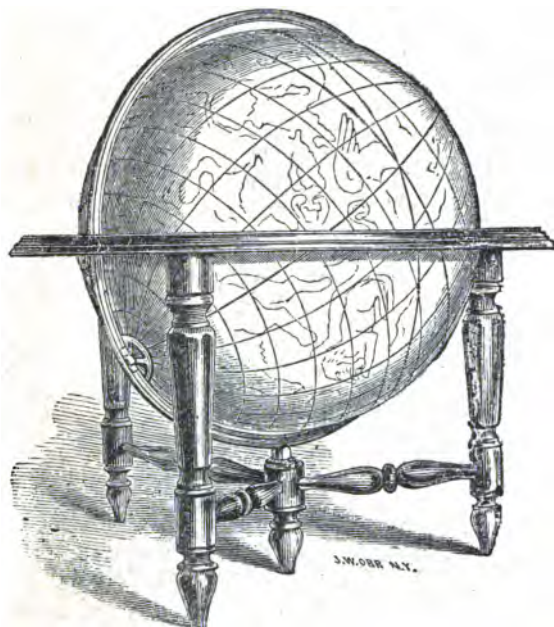
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